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A TEXT-BOOK ON
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BY

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PREFACE.

This short text-book has been written with the object of collecting in a concise form material which has been gathered during many years' experience of the working of the Rivers Pollution Prevention Acts. It aims at describing trade processes so far as to show the origin and nature of polluting waste liquids, and sets out the means which have been found successful in the purification of these.

The authors hope that it may be of service not only to manufacturers and those called upon to advise them, but also to Local Authorities and their officers.

The thanks of the authors are due to numerous manufacturers, some of whom have taken great pains to give particulars of their trade processes and purification works, to several engineers and others who have kindly furnished illustrations, and to many other friends to whom they are indebted for assistance.

H. M. W.

H. T. C.

Wakefield, *March* 1913.

21 FEB 1932

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TRADE WASTE WATERS:

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CHAPTER I.

HISTORICAL AND LEGAL.

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Up to the middle of last century practically all the waste waters produced in trade processes were poured without let or hindrance into the nearest streams. These indeed were looked upon as the natural channels for the reception of such liquids, and, by the Towns Improvement Clauses Act, 1847, Sections 35 and 36, Local Authorities were sometimes even required to discharge their crude sewage into rivers. Such practices, coupled with the rapid industrial development which took place during the first half of the century, led to an intolerable state of matters, to which the attention of the Government was repeatedly directed. At last, in 1865, a Royal Commission was appointed for the purpose of inquiring, amongst other matters relating to rivers pollution,

> "how far by new arrangements the refuse arising from industrial processes can be kept out of the streams or rendered harmless before it reaches them, or utilised or got rid of otherwise than by discharge into running waters."

The labours of this Commission were continued by a second Commission appointed in 1868. As an example of the foul condition of some of the streams at that time, the Commissioners' description of the Rivers Aire and Calder may be quoted, in which they stated that these rivers and their tributaries were abused

> "by the flowing in, to the amount of very many millions of gallons per day, of water poisoned, corrupted, and clogged by refuse from mines, chemical works, dyeing, scouring, and fulling worsted and woollen stuffs, skin-cleaning and tanning" (1865 Commission, Third Report, p. xi).

As evidence of the foulness of the Yorkshire Calder, the Commissioners had, in fact, before them a letter written with its water, and their correspondent writes:

> "Could the odour only accompany this sheet also, it would add much to the interest of this Memorandum!" (1868 Commission, Third Report, p 12).

It seems strange that this state of matters was allowed to develop, for by common law every riparian owner is entitled to receive the waters of a stream unpolluted and undiminished. Experience, however, has shown that only rarely will a riparian owner take the trouble and incur the odium and expense of instituting legal proceedings to maintain these rights. Frequently, indeed, he is himself an offender, and liable to proceedings by others. Moreover, if a pollution continues for twenty years, the common law as to prescriptive rights is a bar to any proceedings by a private person.

The 1868 Commission (First Report, p. 96) reported that

> "of the many polluting liquids which now poison the rivers there is not one which cannot be either kept out of the streams altogether, or so far purified before admission as to deprive it of its noxious character, and this not only without unduly interfering with manufacturing operations, but even in some instances with a distinct profit to the manufacturer; and even in those cases where a certain amount of expense must be incurred in unremunerative operations, the use of the purified stream will more than recompense this expenditure."

In spite of the suggested remedial measures, and notwithstanding the intolerable condition of the streams, several years elapsed before Parliament dealt with the matter.

At the time of these Royal Commissions no public statute had been enacted to deal with trade pollutions. The Gasworks Clauses Act, 1847, following the lines of the Lighting and Watching Act, 1833, forbade the discharge into a stream of any washing or other substance produced in making or supplying gas, and the Waterworks Clauses Act of the same year gave to the owners of waterworks certain powers to prevent pollution. The Salmon Fisheries Act, 1861, imposed penalties upon any person putting any liquid or solid matter into a stream to such an extent as to cause the water to poison or kill fish. The Public Health Act, 1875, except for re enacting the clauses dealing with gasworks, did not deal directly with pollutions by trade refuse, but enacted (Section 15), with certain provisoes, that

> "Every local authority shall . . . cause to be made such sewers as may be necessary for effectually draining their district for the purposes of this Act," and also (Section 21) that "The owner or occupier of any premises within the district of a local authority shall be entitled to cause his drains to empty into the sewers of that authority. . . ."

It has, however, been held that these sections do not apply to trade refuse as distinguished from domestic sewage.

At last, in 1876, stirred up by public opinion and acting on the recommendations of the foregoing and other Commissions, the Government passed an Act dealing expressly with the pollution of rivers by sewage and trade refuse—the Rivers Pollution Prevention Act, 1876. Part I. of this Act makes it an offence to put into a stream, among other solid matters, the solid refuse of any manufactory, manufacturing process, or quarry, so as to interfere with its due flow or pollute its waters. Part III. relates to manufacturing and mining pollutions, and states:—

SECTION 4.—"Every person who causes to fall or flow or knowingly permits to fall or flow or to be carried into any stream any poisonous, noxious, or polluting liquid proceeding from any factory or manufacturing process shall (subject as in this Act mentioned) be deemed to have committed an offence against this Act. . . ."

SECTION 5.—"Every person who causes to fall or flow or knowingly permits to fall or flow or to be carried into any stream any solid matter from any mine in such quantities as to prejudicially interfere with its due flow, or any poisonous, noxious, or polluting solid or liquid matter proceeding from any mine, other than water in the same condition as that in which it has been drained or raised from such mine, shall be deemed to have committed an offence against this Act, unless in the case of poisonous, noxious, or polluting matter he shows to the satisfaction of the court having cognisance of the case that he is using the best practicable and reasonably available means to render harmless the poisonous, noxious, or polluting matter so falling or flowing or carried into the stream."

SECTION 6.—"Unless and until Parliament otherwise provides, the following enactments shall take effect, proceedings shall not be taken against any person under this part of this Act save by a sanitary authority, nor shall any such proceedings be taken without the consent of the Local Government Board: Provided always, that if the sanitary authority, on the application of any person interested alleging an offence to have been committed, shall refuse to take proceedings or apply for the consent by this section provided, the person so interested may apply to the Local Government Board, and if that Board on inquiry is of opinion that the sanitary authority should take proceedings, they may direct the sanitary authority accordingly, who shall thereupon commence proceedings."

"The said Board in giving or withholding their consent shall have regard to the industrial interests involved in the case and to the circumstances and requirements of the locality."

"The said Board shall not give their consent to proceedings by the sanitary authority of any district which is the seat of any manufacturing industry, unless they are satisfied, after due inquiry, that means for rendering harmless the poisonous, noxious, or polluting liquids proceeding from the processes of such manufactures are reasonably practicable and available under all the circumstances of the case, and that no material injury will be inflicted by such proceedings on the interests of such industry. . . ."

Practically, however, this Act remained for many years a dead letter. Its chief defect was that its administration was entrusted to the care of a multitude of Sanitary Authorities, nearly all of whom were themselves gross offenders.

By the establishment of County Councils under the Local Government Act, 1888, this defect was to some extent remedied by placing in their hands the power of enforcing the Act of 1876, and to the action of these County Councils and their Joint Committees the progress that has been made in the purification of streams is almost entirely due. These Councils, having jurisdiction over large areas, and, except in the case of County Boroughs, not being themselves offenders, are in a better position to deal with questions of this kind.

The Act of 1888 provided for the combination of adjoining County Authorities in the administration of the Rivers Pollution Prevention Act, 1876, so that one Joint Committee could be formed to deal with the whole course of a river. Under this provision, which had been recommended by the earlier Royal Commissions, three Joint Committees have been formed to deal with the streams most grossly polluted by waste waters from industrial processes. These are the Mersey and Irwell Joint Committee and the Ribble Joint Committee, which were set up in 1892, and the West Riding Rivers Board, established in 1893. These three Committees consist of members appointed by the County Councils and County Boroughs in the respective areas to administer the Act of 1876. This Act was slightly amended by a short Act of 1893, and the Mersey and Irwell Joint Committee in 1892 and the West Riding Rivers Board in 1894 obtained special Acts, but these add only slightly to the powers given by the former Act. The Middlesex County Council, however, in special Acts of 1898 and 1906, obtained considerably extended powers within its own area.

There are two other Authorities, the Thames Conservancy Board and the Lee Conservancy Board, which exercise jurisdiction as regards pollution practically over the whole area of a watershed, irrespective of county boundaries. The Thames Conservancy was incorporated in 1857, and the Lee Conservancy (a very ancient body) was reconstituted in 1868, but both bodies were primarily intended for the control of navigation. In various Acts which they have obtained from time to time, clauses have been inserted giving them powers to prevent pollution in their respective areas, and by the 1876 Act the Lee Conservancy was specially granted power to administer that Act to the exclusion of other Sanitary Authorities.

The Act of 1876 has important clauses dealing with the reception of trade refuse in public sewers and its subsequent treatment by Sanitary Authorities, which will be dealt with in detail in Chapter XII., but these provisions have been found quite inadequate, and the anomalies in connection with the matter have given rise to great discontent amongst manufacturers and ratepayers Furthermore, the Royal Commissions already mentioned recommended that sewage should always be purified by its application to land, and for many years the Local Government Board insisted upon this being done in all cases where their sanction to a scheme of sewage disposal was requisite, but in the early 'nineties the purification of sewage on artificial filters by biological processes had so far been proved successful as to indicate that the use of land was not always necessary. Consequently, another Royal Commission was appointed in 1898 to inquire and report "what method or methods of treating and disposing of sewage (including any liquid from any factory, or manufacturing process) may properly be adopted." This Commission is still sitting, but has issued numerous reports, several of which deal with the disposal of trade refuse.

In their First Report (1901, p. 13) the Commissioners recommend the creation of a Supreme Rivers Authority to deal with matters relating to rivers and their purification. In their Third Report (1903, pp. 15, 16, and 17) they say

"that sewage containing trade effluents is generally more difficult to purify than ordinary sewage. . . . Our results fully support the view that it is practicable in the great majority of cases to purify mixtures of sewage and trade effluents if the manufacturers adopt reasonable preliminary measures. . . . We are

> satisfied that in some cases at least the purification of the trade effluent by itself would be very difficult to accomplish. . . . We are therefore of opinion that the law should be altered so as to make it the duty of the local authority to provide such sewers as are necessary to carry trade effluents as well as domestic sewage, and that the manufacturer should be given the right, subject to the observance of certain safeguards, to discharge trade effluents into the sewers."

They again (p. 24) lay stress upon the necessity for a Central Authority, and advocate the formation of Rivers Boards throughout the country. Their Sixth Report deals entirely with the disposal of the liquid refuse from distilleries. In another Report, promised at an early date, they will deal directly with pollution of rivers by trade refuse discharges, and in an appendix to their Seventh Report they have already published some of the special evidence which they have obtained on this subject.

Action based on the recommendations of the Third Report has already been taken by several towns. Halifax and Heckmondwike in 1905 and Huddersfield in 1906 obtained the sanction of Parliament to special Acts giving the manufacturers within their areas the right of discharging trade refuse into the public sewers, and empowering the Authorities to make regulations governing these discharges and to charge the manufacturers for the treatment of their refuse in cases where no preliminary treatment is adopted. It is worthy of note that each of these Authorities has adopted the principle of receiving the crude refuse into the sewers and accepting a payment from the manufacturer in lieu of preliminary treatment. Other towns have had the adoption of similar measures under consideration, and would have applied to Parliament had they not been assured annually for several years past by the President of the Local Government Board that he had already prepared a comprehensive Bill based on the Third Report of the Royal Commission and would lose no time in passing it into law.

As the law at present stands any legal proceedings against a manufacturer who pollutes a stream are greatly hampered by restrictions and saving clauses in the Acts of Parliament. These may have been necessary in 1876, when little was known of methods for the purification of trade refuse, but now, after thirty-six years' experience, they chiefly serve to arm the offender who does not wish to comply with the law. In the case of a pollution newly commencing, just as in the case of one which has been continuing for a hundred years, an Authority is debarred from taking proceedings until the sanction of the Local Government Board has been obtained, and in practice this is never given until local inquiry has been held and proof given of the existence of the pollution and of means for its prevention. The same formalities have to be observed even when at an adjoining factory exactly the same kind of refuse has been effectively purified for many years. Moreover, when a new business is being started, in connection with which it is known that there must be polluting discharges of trade refuse, a Rivers Authority has no power to act until the polluting processes are in operation and actual pollution occurs. When the Local Government Board has given consent to the taking of proceedings, two months' notice of the intention to take these proceedings must be given to the offender, and not until the expiration of that period can application be made to the Court for an Order requiring the observance of the law. Further, no provision is made for preventing mismanagement of purification works already constructed, except by again going through all the foregoing formalities.

The history of Parliamentary action in dealing with trade pollution has been, as may be gathered from the foregoing, characterised by delay and weakness. Although by the Towns Improvement Clauses Act, 1847, some attempt was made to lessen the pollution of streams by domestic sewage it was not until 1876 that the much grosser pollution by trade refuse was dealt with, and the restrictions then imposed were such as to give the manufacturer every facility for procrastination or evasion. The reason for this is only too evident, and is well set out by the Right Hon. C. G. Milnes Gaskell in an article in the *Nineteenth Century* in 1903, where he says:

> "The manufacturers were too powerful a body to be compelled to do their duty. 'Parliament,' I once said to Mr Gladstone during the last year of his life, 'has been very lenient to the manufacturers.' 'Say far too cowardly,' replied Mr Gladstone."

After this brief statement of the growth of pollution by manufacturing processes and of the legal measures adopted or contemplated for dealing with it, a description may now be given of the processes from which the waste waters arise and of the methods of purification which have been adopted. This can best be accomplished by dealing separately with various trades, describing each individual process and the methods adopted for the purification of its special kind of refuse. It will, however, be found that there are often several distinct polluting processes at one mill, yielding waste waters which may have to be treated separately and by totally different methods, or may be capable of purification when mixed together. On the other hand, the means of purification which are successful in dealing with one kind of refuse may be equally applicable in other cases, for example, apparatus for adding precipitants, tanks for the removal of suspended matter, or filters for drying sludge.

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CHAPTER II.

THE COAL TRADE.

Polluting discharges—Pit water—Ochre water—Blowing-off boilers and water softening—Coal washing—Object of washing—Forms of washer—Treatment—Bibliography.

IN the coal trade there are many operations in which water is fouled. In pit sinking and in the ordinary course of getting coal large quantities of water are often met with, and these have to be drained into the streams: at many collieries the pit water is used in the boilers, and when it contains dissolved salts in considerable quantity these are deposited and must be blown out from time to time: if the water is previously softened, and this is an increasing practice, there is a similar deposition of solids, which escape in the discharges from the softening apparatus: in many cases the coal is washed to free it from impurities, and the coal-washing water has to be disposed of: where coal is made into coke, water must be used for quenching the hot coke, and is generally used in excess, so that there is a considerable escape of waste water: where gas is manufactured and bye-products are recovered, water is used in many of the incidental processes, such for instance as the recovery of ammonia and of benzol, when very foul liquids may be discharged.

The sources of pollution are therefore as follows:—

1. Discharging pit water.
2. Blowing-off boilers.
3. Water softening.
4. Coal washing.
5. Coke quenching.
6. Manufacturing gas and recovering bye-products.

Pit Water.—In Section 5 of the Rivers Pollution Prevention Act, 1876, an exemption is provided from liability to proceedings under that Act in regard to water in the same condition as that in which it has been drained or raised from a mine. This does not hinder a riparian owner from taking action at common law to stop any pollution caused by such water, provided that a right to discharge it has not been gained by lapse of time, agreement, or otherwise.

When a new shaft is being sunk through water-bearing strata it may be necessary to pump enormous quantities of water from it, sometimes as much as 6000 gallons a minute. To avoid this, the whole of the water-bearing ground through which the shaft is being sunk is occasionally artificially frozen, or rendered solid by the injection of cement, but these are very expensive processes and seldom adopted. When the water is kept under by pumping, it is contaminated by the digging operations and may carry with it large amounts of clay and sand in suspension, and if discharged into a clean stream may affect it very injuriously. In such cases the provision of ponds, through which the water is passed for the settlement of the suspended matters, is generally sufficient, and these ponds should have a capacity equal to six or eight hours' flow. Where the volume pumped is very large, the degree of pollution is naturally less, and treatment of the water may even be unnecessary.

In the newer and deeper pits any water-bearing strata through which the shaft may pass are "tubbed off" to prevent the water reaching the workings, so that after the shaft is sunk there is generally very little to be dealt with. In the older and shallower pits, tubbing has not been so often adopted, and any water met with falls to the lowest part of the workings, and must either be pumped out or drained off by adits. This water is often grossly contaminated by mud and fine coal, and should then be thoroughly settled in ponds or tanks before being discharged to a stream.

Sometimes the water drains from strata containing iron in the form of carbonate, when the escaping water may contain appreciable quantities of iron bicarbonate in solution. When exposed to the air carbon dioxide escapes, and this, together with oxidation, causes a deposit of ferric oxide or ochre, as represented in the equation :—

$$2FeH_2(CO_3)_2 + O = Fe_2O_3 + 2H_2O + 4CO_2.$$

More commonly the iron is present in the strata in the form of pyrites, which, by exposure to air in the mine, becomes oxidised to ferrous sulphate and free sulphuric acid, thus :—

$$FeS_2 + 7O + H_2O = FeSO_4 + H_2SO_4.$$

By further oxidation ferric salts are produced, thus :—

$$2FeSO_4 + H_2SO_4 + O = Fe_2(SO_4)_3 + H_2O.$$

The water issuing from such a pit is highly acid in reaction and contains in solution large quantities of ferrous and ferric sulphates (see Table I.). Occasionally, where oxidation has proceeded further, there are also appreciable amounts of basic ferric sulphate in suspension. When such a water is discharged into a stream, the water of which is alkaline, there is an immediate precipitation of oxide of iron or ochre. Even should the water of the stream not be alkaline, the ochre is deposited, but more slowly, by a gradual oxidation process, or by the metabolism of certain organisms, such as *Leptothrix ochraceæ* or *Crenothrix polyspora*, which are found to grow profusely in ochrey waters. Where a stream receives these discharges it is also contaminated by the free acid which escapes along with the iron salts, and the two pollutions together may attain such a degree that they render the water of the stream poisonous to fish life and to all ordinary aquatic flora and fauna, and unfit for any industrial use. Table I. gives the analyses of a number of ochre waters drained or pumped from coal and gannister mines.

The volumes of such ochre discharges may be very considerable. Mr Percy C. Greaves (Royal Commission on Sewage Disposal, 1898, Seventh Report, vol. 3, p. 158) states that there are many collieries where from 5 to 10 tons of water are pumped for every ton of coal raised. He quotes one case where 2511 tons of ochre water escape from the mine daily, although the output of coal is only 50 tons per day.

The purification of these ochre waters presents no technical difficulty.

Table I.

OCHRE WATERS DRAINED OR PUMPED FROM MINES.

(*Results expressed in parts per 100,000.*)

No.	Total Solids	Solids in Suspension (dried at 100° C.)		Solids in Solution (dried at 100° C.).		Acidity (as H_2SO_4).	Iron (Fe)			Hardness (in terms of $CaCO_3$).		
		Total.	Ash	Total	Ash.		In Suspension	In Solution. Ferrous	In Solution. Ferric	Total.	Permt	Tempy.
1	..	20·8	12·5	.		14·1			66·1		..	..
2		5·2	4·1	.	..	39·2		.	17·4	..	.	..
3	..	Nil.	Nil.			53·1		.	18·5			..
4	436·8	51·8	13·1	385·0	345·0	1·5	7·1	5·0	Nil.	148·4	148·4	0·0
5	56·6	1·6	1·4	55·0	46·0	1·7	0·5	0·8	3·9	31·3	28·1	3·2
6	260·7	5·7	3·5	255·0	163·0	49·0		2·8	20·3	146·8	146·8	0·0
7	207·4	6·4	4·2	201·0	153·2	29·1	3·6	3·9	6·6	133·1	103·0	30·1

The Royal Commission of 1868, in their Fifth Report, dealing with rivers pollution arising from mining operations, say (p. 15):

> "There is indeed a most perfect and efficient remedy for this evil. . . . This remedy consists in adding to the polluted water flowing from the mine, or being discharged from it, a quantity of quicklime (previously slaked) sufficient either to neutralise the acidity of the water or to replace the oxide of iron it contains. About twelve hours' subsidence of the precipitated oxide of iron would then be required."

They point, however, to the great cost which treatment would entail in some cases. Since the date of this Commission much experience has been gained, both here and on the Continent, in the treatment of well waters containing iron so as to make them fit for public water supplies.

Sometimes such waters are treated with lime or soda in a water-softening apparatus, as for instance at Swadlincote and Wellingborough. At Linslade and Fenny Stratford, where the water contains considerable amounts of iron derived from the Lower Greensand, and also at Charlottenburg and some other places on the Continent, where deep-well water carries with it iron in the form of bicarbonate, or held in colloidal solution by humic, ulmic, and other organic acids, the iron is oxidised by passing the water through aerating filters and removed by straining through filters of coke or sand. Oxidation and removal of the iron is also in some cases brought about by forcing the water by means of compressed air through a high-pressure filter of the type described in Chapter XI. Such a process is in use at Hastings, Tunbridge Wells, and several places near Bristol. A similar method would be applicable to these ochre waters, but after the separation of the iron the water would still contain free sulphuric acid. This could be neutralised as suggested above, and for this purpose less lime would be required than if the water had not been previously aerated. The use of manganese "permutit" (see p. 12) for the oxidation and removal of iron has also recently come into use, and promises to be a very efficient process.

TABLE II.

BOILER BLOW-OFF WATERS.

(*Results expressed in parts per 100,000.*)

Nature of Sample.	Total Solids	Solids in Suspension (dried at 100° C.)		Solids in Solution (dried at 100° C.).		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total.	Ash		Total.	Permt.	Tempy.
Water used . .	128·6	5·6	1·1	123·0	103·0	..	43·0	6·5	36·5
Boiler blow-off .	878·6	37·6	29·8	841·0	824·0	..	21·0	13·5	7·5
Water used . .	86·7	2·8	0·3	83·9	62·3	0·08	88·5	20·3	68·2
Boiler blow-off .	1973·0	752·0	607·0	1221·0	1184·0	8·20	..	..	..
Boiler blow-off .	871·1	666·7	556·9	204·4	159·2	0·70	153·1	90·0	43·1
Boiler blow-off	501·4	188·6	99·5	312·8	266·0	32·53	80·5	75·0	5·5

Any of these processes, however, would be costly if applied to the large volumes of water which are discharged from mines. In practice it is found that if these ochre waters are passed through shallow ponds they deposit much of their contained iron and thus lose much of their polluting character.

Blowing-off Boilers and Water Softening. As has already been stated the water pumped from a coal pit is often used for feeding boilers, and as such a water is frequently extremely hard (see Tables II. and III.), its use brings about the deposit of large quantites of mineral salts in the boilers. Such a deposit may either occur as a finely divided sludge or may form a hard scale on the boiler plates. In the former case the inconvenience may not be great, as the sludge can from time to time be blown out, but the discharge thus produced contains far too many suspended solids to be allowed to reach a stream. Table II. contains analyses of the water used in several such cases and of the polluting discharges when the boilers are blown off.

When the deposited solids take the form of a hard scale the injurious effect of the use of such a water becomes very marked. The scale is a bad conductor of heat, so that increased quantities of fuel are necessary: the removal of the scale when the boiler is cleaned is a matter of difficulty and expense, and the chiselling necessary is liable to injure the boiler plates: when the scale is very thick it may at any time crack and allow the water to reach the overheated plate, when there is great risk of an explosion from the sudden production of steam. Where economisers are used in connection with the boilers they are even more injuriously affected, as the tubes rapidly become choked by the deposited solids.

For the above reasons it is a very general practice to soften these hard waters before use by means of chemical precipitation and settlement. One case may be quoted where before a softening process was adopted twenty-two boilers were necessary and found scarcely sufficient, whereas after the introduction of a water softener eighteen boilers were sufficient, and these required considerably less fuel per boiler. The solids settled in such a process must be discharged from the softening plant in the form of a liquid sludge very similar to that from blowing-off boilers.

Such liquids are easily purified by simple settlement, as the solids in suspension are readily deposited. Tanks should be provided large enough to contain the maximum discharge at any one time, and these should be at least in duplicate, so as to allow time for settlement and cleansing. They should be provided with efficient means for letting off the top water without disturbing the sludge. The sludge thus produced consists for the most part of carbonate of lime in very fine subdivision, and this is stated by J. Hendrick, B.Sc., F.I.C. (*Chemical Trade Journal*, 21st September 1912, p. 295), to be very useful for agricultural purposes.

A new process has recently come into use for softening hard waters, by means of "Permutit," which does not produce the liquid sludge discharged from the older processes. The water is passed through a filter of artificial zeolite, an aluminate-silicate of sodium, which has the property of displacing the calcium and magnesium of the salts in the water by the sodium of the zeolite. After the filter has run for some time it must be regenerated, and this is accomplished by treating it with a small volume of a strong solution of sodium chloride, when the deposited calcium or magnesium permutit is again decomposed, with formation of sodium permutit and calcium or magnesium chloride. These latter salts are washed out, and the washing water is exceedingly hard, and if discharged to a stream would in some cases be obnoxious to users of the water lower down. In such cases the adoption of this process is not advisable. Sometimes, however, where this process of water softening is adopted at a mill where soapy liquids are discharged, the calcium and magnesium chlorides in the washing water from the filter might be used as precipitants for the soap.

As has been mentioned, a manganese permutit can be used for the removal of iron from water, a process which also sterilises by the action of the higher oxides of manganese. In this case the regeneration of the permutit is effected by means of a permanganate solution.

Coal Washing.—The Rivers Pollution Commission of 1868 paid a good deal of attention to the pollution of streams by water fouled in coal washing, and investigated the effect of this pollution on the Derbyshire part of the River Rother (see Fifth Report, vol. 1, p. 7, and vol. 2, pp. 186 *et seq.*). In a paper by Mr George Howe, reprinted by the Commission (Fifth Report, vol. 2, p. 192), it was clearly shown that all pollution of the stream by coal-washing refuse could readily be prevented, and that not only were the means required very simple, but that their adoption would be profitable to the colliery owner. Similar evidence has been given before the present Royal Commission by Mr P. C. Greaves (Seventh Report, vol. 3, Q. 30270–1), who stated that at practically all the collieries with which he is connected means have been adopted to purify this kind of refuse.

Since the 1868 Commission reported there has been a very great increase in the number of places where coal is washed, and had it not been found easily practicable to purify the water discharged, the resulting pollution of the streams from this cause would have been very great. The coal raised annually in the United Kingdom amounts to about two hundred and seventy million tons. Of this amount over thirty-five million tons are converted into coke, 60 or 70 per cent. of it being previously washed, and a proportion of the coal which is not made into coke is also washed before it reaches the consumer. Moreover, the amounts of coal raised and coke produced are increasing year by year.

An interesting report on the various methods of coal washing is given in the *Transactions of the Mining Institute of Scotland* for 1889, and although since then considerable modifications and improvements in the washers have been introduced, these have made little difference in the character of the effluent produced. Their effect has, however, been to reduce the quantity of dirty water finally discharged, for in nearly all modern washers the same water is circulated again and again. A more recent paper, descriptive of modern coal washers, has been written by W. McD. Mackey, F.I.C. (*Journ. Soc. Chem. Ind.*, 1904, vol. 23, p. 431).

The following brief description may serve to explain the principles of the process, which is not one of washing in the ordinary sense of the word, but rather a separation of the coal from its impurities by means of agitation in water. Coal as it comes from the pits often contains a considerable admixture of impurities, such as shale, clay, and pyrites, which greatly reduce its value, and especially so in the case of coal which is to be converted into coke for use in the iron and steel industries. The larger pieces of stone and shale can be picked out of the coal by hand, but when the coal and its impurities are broken up into small pieces this method of separation is impracticable, and it becomes necessary to wash the coal. The impurities are almost invariably of greater specific gravity than the coal, and when a mixture of small pieces of the two is agitated in water, they gradually separate into two layers, the coal at the top, and the "dirt" at the bottom. All washing machines are constructed to take advantage of this difference in specific gravity, and are so arranged that the dirt is discharged from one part of the washer, whilst the coal issues with the water from another part. The coal is separated from the water either by straining or settlement, but the water which finally escapes usually carries with it large amounts of fine coal in suspension.

Mr Mackey in his paper says that

> "the simplest and probably the earliest form of washer was the trough, consisting of a trough or spout usually with wooden sides, and, in the later forms, glass slabs on the bottom to withstand the action of the water and grit. The trough is about 2 feet wide, and set at a slight slope, and extending as a rule not less than 40 feet. Down this the water runs, carrying the coal, and dams set at intervals catch the dirt, the clean coal passing on. These troughs are usually worked in pairs, one being cleaned whilst the other is at work.
>
> "The modifications of the trough form a class which we may take first. Thus, in the 'Elliot' washer, an endless belt of dams is made to travel up against the flow of water and coal, delivering the dirt at the upper end. The 'Murton' consists of an endless belt of steel trays with dams attached, carrying the dirt against the flow of coal and water, and delivering it at the upper end. In the 'Muschamp' the dirt is made to travel to the upper end by means of a screw (the screw in this case forming the dams); and, lastly, the 'Blackett' consists of a steel tube or cylinder (30 feet long, and 4 feet in diameter) which turns as the coal and water flows from one end to the other, the tube being laid laterally at a slight slope. A screw is attached to the inside of the tube, and as the tube revolves, the dirt falling behind this screw, which forms a continuous dam, is taken to the upper end of the tube and discharged. The coal to be treated (along with part of the water) is delivered by a stationary spout running to about the middle of the tube, and the dirt gets a further washing when it passes this point by a stream of water which enters at the upper end.
>
> "To a second class belong washers of the jigger or pulsating type. This includes the German washers, the 'Luhrig,' the 'Humboldt,' the 'Baum,' and one at least of English make, the 'Sheppard.' Washers of this type consist essentially of a grid through which water rises and falls, being actuated either by a ram or compressed air. Water and coal are led on to the upper surface of the grid at one end, and the clean coal, which is separated from the dirt by the quick upward jig of the water, is discharged with the stream of overflow water at the other. The dirt, which forms a lower layer, partly finding its way through the grid and partly being discharged into the chamber below by an opening at the further end of the grid, collects in the bottom of the chamber, and is brought out by a screw conveyer. In some cases the grid is covered with felspar, through which the dirt makes its way, and usually a washer consists of several chambers and grids for coals of different sizes, the most vigorous pulsations being given to the water for the larger sizes. In the 'Baum' washer, in its latest development, all sizes are treated over one grid, and the coal sized after washing.
>
> "A third class is represented by the 'Robinson' washer, which consists of a vessel in the shape of an inverted cone, into which the coal is charged at the top, and an upward current of water, which overflows at one side, carries with it the clean coal, whilst the dirt sinks and is removed by a false bottom arrangement. The separation of the coal and dirt in the washer is facilitated by moving arms or paddles.
>
> "Recently, as a fourth class, we have table washers of the gold-washing type. Of these the 'Craig' is the best known in England. It consists of a steel table, on to which the coal, previously mixed with water, is led, and over which the clean coal floats and is discharged at the further end, whilst the dirt, by an ingenious back bump arrangement, is caused to travel in the opposite direction and to be discharged off the table. In this way very fine or ground coal can be washed, but the rate of washing is slow, not exceeding five tons per hour."

Since the above paper was written, other forms of washers have been introduced, for example, the "Primus" and the "Greaves," in which the dirt is separated from the coal by means of a perforated tray to which a jigging motion is given under the surface of a tank of water. This produces the same effect as in the washers of the pulsating type already mentioned, in which the perforated tray is fixed and the water pulsates.

As the water used in coal washing need not be very pure, that which escapes from the washer is now usually caught in a tank and pumped back for re-use, with the double object of economising water and avoiding the waste of the fine coal in suspension. The receiving tank should not be large enough to permit of sedimentation, for the fine coal must be kept circulating with the water so that it is continuously being returned to the washer. If allowed to settle it cannot afterwards be uniformly mixed with the rest of the coal and cannot by itself be made into marketable coke.

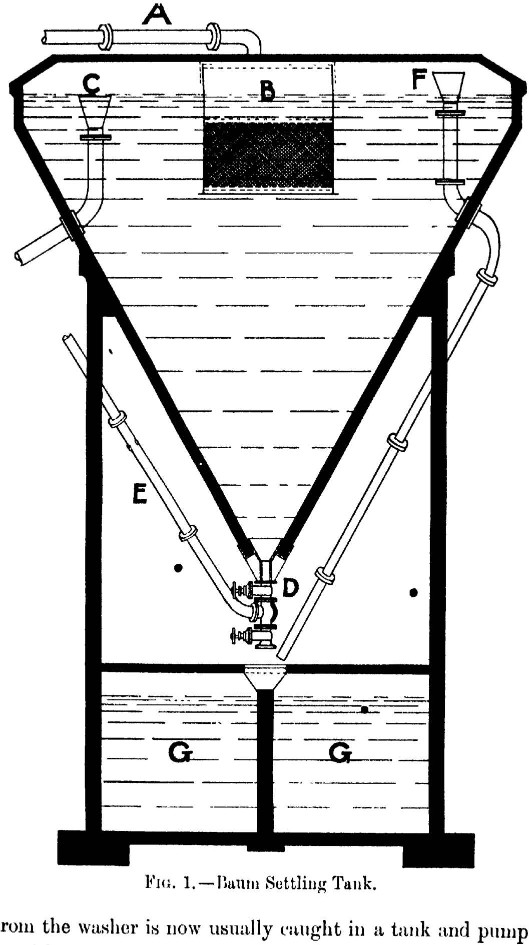

FIG. 1.—Baum Settling Tank.

In some washers the uniform admixture of the fine coal is attained by quite a different method, which also has the advantage of clarifying the water used. In this method the washed coal and water are both discharged into a large hopper, from the bottom of which the water is allowed to drain away, the coal acting as a very effective strainer.

This admixture is also accomplished by the Baum settling tank of the Simon Carves Bye-product Co. (Fig. 1), which consists of a tank in the shape of an inverted cone erected on columns so that the water can run from it to the washer by gravitation. All the water is drained from the washer into a sump from which it is pumped through a pipe, A, into a hollow sheet-iron cylinder, B, the lower half of which is perforated. The water escapes laterally through the perforations, and the solids fall to the bottom of the tank, where the slurry collects. The water escapes from the tank by the overflow, C, which returns it to the washer. The head of water in the tank forces the slurry through the regulating tap, D, and up the pipe, E, from which it is delivered on to the band conveying the washed coal from the washer. To prevent the water from running over the sides of the settling tank, an overflow, F, is arranged which takes the excess water into storage tanks, G. These are in duplicate, so that one can be in use while the other is being cleaned out. The whole contents of the conical tank can be let off into G.

The circulation and re-use of the washing water may, in some cases, be carried on continuously, when there need be no discharge of dirty water from the washer; on the contrary, fresh water must be added to replace that which is absorbed by the coal and dirt. In other cases, where considerable quantities of salt or finely divided clay are washed out of the coal, the water ultimately becomes so full of these impurities that it has to be discharged as refuse. This dirty water is very polluting in character, as it contains large amounts of solids in solution dissolved out of the coal, and still larger amounts of solids in suspension, these latter consisting in great part of finely divided coal. In Table III. are given the analyses of a number of samples of water taken directly from various washers, and, for purposes of comparison, the analyses of the same waters before use.

It will be noted that most of the waters used contain large amounts of mineral matter in solution. This is due to the fact that they have been pumped from the pits, the usual source of the water used in coal washing. These pit waters are almost invariably found to contain much dissolved mineral matter, especially chloride of sodium; for instance, the water from one pit in the South Yorkshire Coalfield contained 10,820 parts of this salt per 100,000, although, of course, this water was not being used for coal washing. Similar soluble mineral matters are dissolved from the coal in the process of washing, and in thirty-two analyses of effluents the amount of chlorides present has been found to vary from 5 to 906 parts per 100,000. Several effluents were tested for arsenic, but none were found to contain it.

At one time the water from the washers was frequently discharged to the streams without treatment, but any such discharges now taking place must be the result of accident or gross carelessness. The colliery owners are now, for the most part, fully alive to the loss of good coal when the water is allowed to escape directly from the washers, and take good care to prevent it. Recently, indeed, at several collieries, special washers have been provided for re-washing the sludge escaping from the primary washers, so that the coal in it may be recovered and made into coke.

The solids in suspension in the water from the washers are usually capable of rapid settlement. Sometimes, however, the waste waters contain very finely divided clayey matters which only settle with difficulty, but this can be met by the addition of small quantities of lime water (see Patent No. 763, 1911, W. McD. Mackey), as in the sedimentation of china clay in the manufacture of porcelain.

TABLE III.

COAL-WASHING WATERS BEFORE AND AFTER USE.

(*Results expressed in parts per 100,000*).

Sample.	Total Solids.	Solids in Suspension (dried at 100° C.)		Solids in Solution (dried at 100° C.).						
		Total	Ash	Total	Ash.	Siliceous Matter.	Calcium Salts (as CaO).	Magnesium Salts (as MgO).	Chlorides (as NaCl),	Sulphates (as SO_3).
Water used .	78·27			78·27	71·42	1·25	11·10	8·00	14·64	22·85
From washer	840·00	291·80	91·80	548·20	492·20	2·00	37·85	18·82	444·28	32·42
Water used	126·28			126·28	112·00	0·91	15·61	12·37	23·42	40·50
From washer	4,500·42	4,345·28	290·00	155·14	141·00	0·71	16·73	10·70	50·37	41·27
Water used .	180·64			180·64	154·00	0·49	21·94	15·54	19·28	66·07
From washer	12,845·86	12,189·86	3403·43	356·00	333·00	0·60	23·37	14·41	196·14	69·42
Water used .	28·24			28·24	2·24	0·15	4·15	1·50	5·28	7·27
From washer	14,922·42	11.674·00	2017·35	218·42	243·21	0·80	10·07	2·08	205·14	21·97

As has been previously described, the modern practice is to circulate the water for re-use, and the claim is often made in the case of new washers that there will be no discharge of dirty water from them. In the case of even the best washers, however, at times when they are stopped, say for repairs, the water they contain must be discharged, and settling tanks must therefore be provided to contain this quantity of water. In most cases, and especially if fine clay or salt is washed out of the coal, a constant escape of surplus water must be anticipated, and, at frequent intervals, a discharge of all the water in the washer for cleansing purposes. There is, moreover, generally a quantity of dirty water draining away from the waggons of wet coal or dirt.

An accurate estimate of the quantity of water used is very difficult to obtain, and few colliery proprietors have been able to furnish it. It has been variously estimated at from 600 to 2400 gallons per ton of coal washed; while to the Royal Commission of 1868 it was stated by one witness (Fifth Report, vol. 2, p. 187) to be 600 gallons per ton, and by another (p. 193), 1120 gallons.

In one case in which the water is mostly re-used the information has been obtained that 990 gallons of water which has passed through the washer are pumped back for re-use for every ton of coal washed, while at the same time 135 gallons of clean water per ton are pumped into the washer. Some of this latter quantity will be absorbed by the coal and dirt removed from the washer, since small coal when washed will retain some 10 to 15 per cent. of moisture, so that not more than 100 gallons per ton will escape and require to be purified. These figures give a total quantity of 1125 gallons of water required to wash a ton of coal, and one-eleventh part of this as final effluent. In another case, where also most of the water is re-used, 125 gallons of clean water are pumped into the washer for every ton of coal washed, but no estimate can be obtained of the amount of dirty water re-used.

For the purification of this kind of refuse the means adopted are almost invariably in the form of settling tanks or ponds. The 1868 Royal Commission (Fifth Report, vol. 1, p. 43) recommended that subsidence tanks should be provided of such a size that the waste waters can remain at rest for six hours; but the method of continuous flow settlement is now almost invariably adopted, when the tanks should have a capacity equal to half a day's maximum flow (cp. Royal Commission on Sewage Disposal, 1898, Fifth Report. p. 229), and should be in duplicate to permit of cleansing. In certain cases, where much clay escapes with the coal-washing water, or an exceptionally pure effluent is necessary, some form of straining filter may also be required, and this is usually made of fine coke breeze or furnace clinker, materials which are plentiful at every colliery.

The following diagrams (Figs. 2 and 3) show the kind of works which have been constructed. They require very little explanation. The first figure is that of a plant from which there is an effluent regularly discharged, and the second of one from which there is usually no effluent to the stream. The effluent in the former case comes from a washer dealing with 80 tons of coal per day, and has been frequently practically free from suspended solids: in the second case the washer deals with 400 tons of coal a day; so that one may be considered a small plant and the other comparatively large, the average capacity of washers being about 300 tons of coal per day.

Mr Mackey, whose description of coal washers has been quoted above, has devised a patent plant (Patent Nos. 11,410, 1905, and 1327, 1911) for the removal of finely divided suspended matter from a liquid, and has applied this to the treatment of coal-washing water with the double view of clarifying the water for re-use and recovering the solids so that they can be mixed with the washed coal. This plant is a modified form of that shown in Fig. 22 (p. 140).

Results of the treatment of coal-washing waters are given in Table

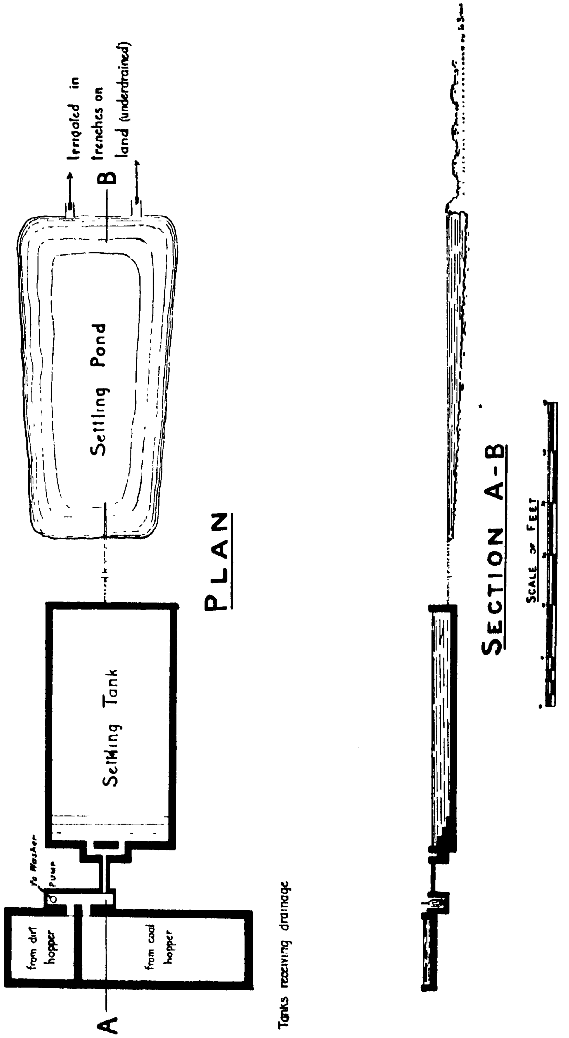

FIG. 2.—Works for treating Coal-washing Water.

IV., but it must be borne in mind that in the most satisfactory cases, as has already been stated, all the water is constantly re-used, and none escapes to the streams.

It will be noticed that the effluents in Table IV., although usually satisfactory in regard to the amount of solids in suspension, contain large quantities of solids in solution, which in some cases might be extremely detrimental to the use of the water, say in the textile industries. For such use it might be necessary to adopt some softening process.

In order to safeguard the streams and to recover as much water as possible it is advisable at every colliery to have final settling tanks or ponds situated as low as circumstances will permit, so as to be available for the interception not only of the surplus water from the washers, but also of the surface drainage from the whole of the colliery premises. These ponds can readily be constructed by forming banks across a small valley or around a flat area with the spoil from the pit. The waste

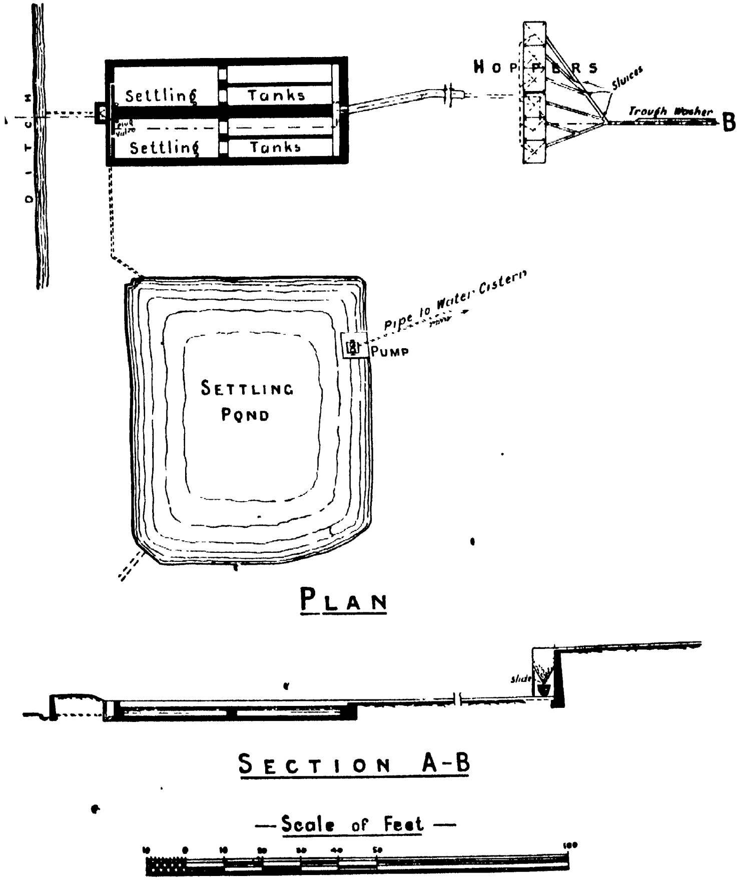

FIG. 3.—Works for treating Coal-washing Water for re-use.

waters, when turned into such a pond, will percolate through the banks, and, thus filtered, may be made fit to discharge to a stream or to be re-used at the colliery. When the pond becomes full of settled solids its banks can easily be raised by further tipping. In some cases ponds of this kind have been made a quarter of an acre in area and with banks 25 feet high.

It is gratifying to find that the measures of purification adopted by colliery proprietors have resulted in a great saving to them. When the dirty water from the washers was discharged untreated to the streams, a much larger quantity of water was needed for washing the coal, and it carried with it a large amount of good coal in suspension, amounting in some cases to 200 tons per week. This coal is now almost always recovered and mixed with the washed coal. Where this is not done it can be used for burning in the colliery furnaces. It has also been proposed to form it into briquettes, either by itself, or mixed with sewage sludge or some form of petroleum refuse, and to use it in a Mond or similar apparatus for the production of gas and ammonia.

TABLE IV.

COAL-WASHING WATERS AFTER TREATMENT.

(Results expressed in parts per 100,000).

Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Hardness (in terms of $CaCO_3$).		
	Total.	Ash.	Total.	Ash.	Total.	Permt.	Tempy.
412·00	4·80	1·60	407·2	346·4	...	...	...
340·00	2·00	1·00	338·0	314·0	...	...	...
206·90	1·90	1·90	205·0	175·0	...	...	...
180·60	2·60	1·00	178·0	164·0	...	...	...
954·10	4·10	3·10	950·0	822·0	...	...	...
309·30	5·70	4·20	303·6	276·4	...	...	...
368·80	0·80	0·48	368·0	346·0	...	...	...
543·08	1·88	0·56	541·2	467·2	221·8	196·0	25·8
244·00	2·00	1·52	242·0	218·6	90·1	59·0	31·1
625·00	3·70	3·00	621·3	528·3	228·5	185·7	42·8
293·68	1·68	1·12	292·0	268·4	110·5	59·0	51·5
263·92	3·52	2·24	265·8	235·2	56·0	45·7	10·3

Coke Quenching, Manufacturing Gas, and Recovering Bye-products.—Although these processes are now in use at a large and increasing number of collieries, they are more frequently found in connection with public gasworks, and the gas liquor and bye-products are often manipulated by chemical manufacturers. The waste liquids discharged do not therefore concern the coal trade alone, and can best be dealt with in a separate chapter, in which are grouped all the polluting processes relating to the manufacture of gas.

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CHAPTER III.

COAL GAS MANUFACTURE.

Extent of industry—Coke quenching—Recovering bye-products—Gas liquor—Benzol recovery — Spent gas liquor — Law dealing with chemical refuse — Methods of purification—Fowler's method—Radcliffe's methods—Grossmann's method—Wyld's method — Use of ozone — Other methods of disposal—Evaporation — "Direct" processes of recovering ammonia — Koppers' process — Otto-Hilgenstock process—Simon-Carves plant—Storing gas—Power gas—Suction gas—Bibliography.

THE distillation of coal, whether primarily for the production of gas, as at gasworks, or for the manufacture of coke, as in coke ovens, is a great and increasing industry. Table V., abstracted from the *Home Office Report on Mines and Quarries for 1910*, Part 3, p. 224, shows the annual production in the United Kingdom of coke at gasworks and at coke ovens during 1909 and 1910.

TABLE V.

Year.	Coal Used in Manufacture of Coke (Tons).	Coke Obtained (Tons).	
		At Gasworks.	At Coke Ovens.
1909	34,514,573	7,370,598	11,496,551
1910	34,964,208	7,406,346	11,925,115

In the older process of coke manufacture, the ovens used are all of the "beehive" type, in which no attempt is made to recover the gas produced, but these are gradually being replaced by patent ovens of various types, the gas from which is utilised and its bye-products recovered. The number and kind of ovens in use in the United Kingdom are shown in Table VI., which is also abstracted from the above Report, p. 224.

Coke Quenching.—At all gasworks and at collieries where coke is produced, whether in beehive or patent ovens, water is required for quenching the hot coke. At ordinary gasworks the coke is usually spread out on a stone floor and cooled with water, played upon it from a hose. The amount of water which escapes is generally not large, but there may be some excess, and this may carry with it sufficient fine coke in suspension and dissolved impurities to render it unfit to discharge to a stream (see Table VII.). In the case of collieries where beehive ovens are used, the quenching usually takes place in the oven itself, and the whole of the water is generally evaporated.

The coke produced in patent coke ovens is sometimes also quenched by water from a hose, but, as the coke bench upon which the hot coke rests usually slopes considerably, the amount of water which escapes may be large. More especially is this the case when a mechanical quencher is used. This is an apparatus in the form of a hood, under which the hot coke is pushed as it emerges from the oven, and from the inside of which water at a high pressure is directed upon the coke from a number of jets. When this method of quenching is adopted nearly a ton of water is used for every ton of coke, and of this amount nearly half a ton escapes evaporation and drains away, but this can be caught and re-used, so that there is no need for any coke-quenching water to be discharged as refuse.

TABLE VI.

Kind of Oven.	Number in Use.	
	1909.	1910.
Beehive	17,393	16,037
Coppee	1,959	1,991
Simon-Carves	1,143	1,140
Semet-Solvay	842	1,055
Otto-Hilgenstock	948	1,025
Koppers	408	507
Simplex	256	334
Huessener	239	249
Bauer	52	52
Collins	45	45
Mackey-Seymour	32	32
Other kinds	865	516
Total	24,182	22,983

The escaping water contains, as has been stated, a large amount of finely divided coke in suspension, as well as some matters in solution which have been extracted from the coke (see Table VII.). It must not be assumed that the solids noted in these analyses of coke-quenching waters have all been extracted from the coke, for on comparing them with the amounts in the waters used it is evident that the latter contained much solid matter in solution. The suspended coke deposits readily in settling tanks, and the liquid remaining is usually pumped back for re-use. The settling tanks should be made large enough to hold at least four hours' maximum flow and should be in duplicate to allow of cleansing, and the overflow from these tanks should be received in a storage tank from which the water can be pumped back. If any impure liquid, such as that from ammonia stills, is mixed with the coke-quenching water, then care should be taken that all is continuously re-used. Where clean water only has been used for quenching, the effluent from the settling tanks can be entirely freed from suspended matters and tarry particles by being strained through a fine bed of coke or a filter of wood shavings, and may then be used for any of the colliery purposes, or may even be discharged to a stream without detriment; but, as has been shown, the process consumes large quantities of water and there is therefore no need to allow any to escape.

TABLE VII.

COKE-QUENCHING REFUSE.

(*Results expressed in parts per 100,000.*)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100 C)		Solids in Solution (dried at 100° C.).		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7 C.	Hardness (as $CaCO_3$).		
		Total.	Ash.	Total.	Ash.		Total.	Permt.	Tempy.
From gasworks:									
Crude . .	41·5	10·4	3·6	31·1	19·4	1·66	25·1	19·4	5·7
Crude . .	100·6	15·0	6·4	85·6	61·6	2·48	41·4	40·8	0·6
Settled . .	69·6	1·6	1·1	68·0	56·0	0·52	..	..	..
From coke ovens:									
Water used .	141·0		..	141·0	130·0	0·09	..	..	..
Crude . .	2207·0	2034·0	702·8	173·0	159·0	11·84	..	..	..
Water used .	798·1	1·9	0·9	796·2	644·4	0·64	110·9	83·5	27·4
Crude . .	997·4	119·6	64·4	877·8	755·2	3·60	133·1	133·1	0·0
Water used .	206·2	0·2	0·2	206·0	184·4	0·14	31·9	18·6	13·3
Crude . .	908·3	668·9	167·7	239·4	215·2	22·45	59·7	39·8	19·9
Settled . .	509·6	6·8	3·8	502·8	443·8	1·43	..	..	..
,, . .	117·7	19·7	15·5	98·0	85·0	0·80	40·7	37·6	3·1
,, . .	181·5	1·9	0·6	179·6	121·5	2·26	73·4	68·0	5·4

Recovering Bye-Products. In the manufacture of gas large quantities of "gas liquor" are produced. It was at first looked upon entirely as trade refuse, but its treatment for the recovery of the ammonia it contains was soon undertaken, and this ammonia now yields a very considerable profit. The works at which ammoniacal liquor is produced or dealt with are either ordinary gasworks, or the premises of chemical manufacturers, patent coke ovens, blast furnaces, shale-oil works, or works where gas producers have been installed.

In many of the larger gasworks a plant is provided for the distillation of the ammonia from the gas liquor, but fortunately in the great majority of gasworks the liquor is not manipulated on the spot, but is stored and sold to chemical manufacturers. This greatly reduces the number of polluting discharges, although it does not lessen the quantity of polluting liquid discharged.

Within the last few years patent coke ovens have been introduced at many collieries, and from these the gases are recovered, and incidentally large quantities of gas liquor are produced, which are invariably distilled on the premises. Another source of somewhat similar pollution which may increase in the near future occurs in connection with the manufacture of power gas (see p. 44).

At blast furnaces where coal is the fuel used, as is generally the case in Scotland, much gas escapes from the furnaces, and this is washed for the recovery of its ammonia. At works where shale is distilled for the oil it contains, gas liquor is also produced, and is treated like that from gasworks.

The increase in the quantity of gas liquor produced, which has been very great in recent years and will be still greater in the immediate future, is thus little dependent upon the manufacture of gas for illuminating purposes, but is due first to more economical methods of manufacturing coke, in which the gases which were formerly burned to waste are now recovered and treated for the separation of ammonia and other bye-products, and secondly to the increasing manufacture of gas to be used either as fuel for boilers or directly for power production in gas-engines.

TABLE VIII.

Source.	Sulphate of Ammonia (tons) Annually Produced.							
	1898	1900.	1902.	1904.	1906.	1908.	1909.	1910.
Gasworks . . .	129,590	142,419	150,055	150,208	157,160	165,218	164,276	167,820
Coke ovens . .	5,403	10,393	15,352	20,848	43,677	64,227	82,886	92,665
Shale works . .	37,264	37,267	36,931	42,486	48,534	53,628	57,048	59,113
Iron works . . .	17,935	16,959	18,801	19,568	21,284	18,131	20,228	20,139
Producer gas and carbonising works (bone)	6,165	6,688	8,177	12,880	18,736	24,024	24,705	27,850
Total . .	196,357	213,726	229,316	245,990	289,3[illegible]1	325,228	349,143	367,587

Table VIII., abstracted from the Annual Reports of the Chief Inspector of Alkali Works, will give some idea of the rate at which the production of gas liquor is increasing. It shows the annual production of sulphate of ammonia from various sources within the United Kingdom.

Gas liquor is produced in the dry distillation of coal, or, in other words, in the conversion of coal into coke, in two ways. When the coal is heated in retorts or closed chambers it gives off a large quantity of gas and vapour, which is received from the retorts into a hydraulic main, and there tar and gas liquor are condensed. The gas passes on through coolers, usually formed of serpentine pipes cooled externally by air or cold water, in which more tar and gas liquor separate. The gas is then passed through a tar extractor, usually in the form of baffle plates upon which the tar collects. The mixed tar and gas liquor are run into a general storage tank in which they separate into two layers, a lower of tar and an upper of gas liquor, and from which they are taken separately for further manipulation.

The gas from which the tar and gas liquor have condensed is rich in ammonia, for the recovery of which, as well as for the purification of the gas, it is passed through a series of towers called "scrubbers" or "washers," where it meets a spray of water. This absorbs the ammonia and, at the same time, a large number of tarry matters and sulphur compounds, and is then also known as gas liquor. It is usually also run into the general storage tank.

In order to reduce the quantity of water used and to produce a stronger gas liquor, as well as to dissolve the fixed ammonia salts out of the tar and to keep the tar moving, part of the water from the scrubbers is often pumped instead of clean water into the hydraulic main to form the water seal, and by proper management a further great reduction can be economically effected in the amount produced in the scrubbers. These are usually arranged in a series of three, through which the gas is passed consecutively, and by using clean water in the last of the series, pumping it up for re-use in the second, and again, as it escapes from the second, pumping it up to the first, the amount of water required is at once reduced to a third, while at the same time the gas liquor is proportionately stronger.

Gas liquor, whether obtained from the manufacture of gas in gas-works, or as a bye-product from other processes, contains ammonia in two forms, free, and fixed in combination with acids. This ammonia is recovered by distillation in two stages, the liquor being first heated by itself, by means of live steam, when the free ammonia and a certain amount of volatile ammonium salts escape, and afterwards with the addition of lime, which sets free the ammonia which has been combined with the stronger acids. The gas liquor from blast furnaces and shale-oil works contains so little fixed ammonia that it is generally distilled without the aid of lime. The ammonia escaping from the still is passed into strong sulphuric acid in a "saturator," where it is seized upon by the acid to form crystals of sulphate of ammonia.

The hot vapours which pass from the still through the acid are cooled and condensed in a series of pipes into a grossly polluting liquid which is known as "devil water." This liquor is sometimes discharged as refuse, but is generally, and should be always, returned to the storage tank for gas liquor and circulated again through the still. The bulk of the refuse, however, comes from the still, being the spent gas liquor after the ammonia has been driven off, along with the lime which has been added in the process of distillation. Modern stills are always so constructed that the crude gas liquor is continuously entering at the top, and the spent liquor, with the spent lime, escaping at the bottom. Other subsidiary polluting discharges, such as occur from leaky pipes, surface drainage, and the spilling of tar and oils, are only small in amount and can readily be prevented.

One such subsidiary discharge in the case of some patent coke ovens may be specially mentioned. The gas, after passing through the washers where the ammonia is dissolved out by water, is very rich in benzol, which forms another valuable bye-product. This is extracted by passing the gas through a scrubber in which tar oils (creosote) are used instead of water, because benzol is soluble in the former but not in the latter. This solution of benzol in creosote is distilled like the gas liquor, first with the aid of a current of live steam, and finally by means of heat applied by a steam coil, which drives over the benzol mixed with the vapour of water. These in condensing separate into two layers, an upper of benzol and a lower of water, and the water, although fairly bright and clear, is still grossly polluting, and quite unfit to discharge to a stream. It contains, however, a considerable amount of ammonia, and can with advantage be run into the gas-liquor tank, as is done in some cases, or can be used for the absorption of further ammonia in the washers. The tar oils from which the benzol has been distilled are re-used for the absorption of more benzol, and are too valuable to be discharged as liquid refuse. When they become too highly charged with impurities to be fit for re-use, they are sent to the tar distillers for redistillation.

The spent gas liquor leaving the ammonia stills is a light brown liquid of a temperature of some 100° C., turbid with particles of spent lime and tarry matters, and having a peculiar offensive smell. From the presence of the lime, it is strongly alkaline and exceedingly hard. Most of the lime settles readily, leaving a comparatively clear liquid, the chemical composition of which is somewhat complex. It is sufficient for the purpose of showing its polluting character to say that it still has a brown colour and an offensive smell, and contains large amounts of acidic and basic tar oils and noxious sulphur compounds, that the oxygen it absorbs in the permanganate test is exceedingly high, and the hardness, partly temporary but chiefly permanent, very marked. Analyses of both crude and spent gas liquors are given in Table IX.

The effect of a discharge like this upon a small stream is disastrous, the water being rendered poisonous to fish and cattle, offensive and discoloured, and unfit in fact for any of its ordinary uses. Moreover, the great capacity of the refuse for absorbing oxygen is very detrimental to the stream in preventing the self-purification which goes on in all streams under ordinary conditions.

The law relating to this form of pollution is clear and distinct. By common law a riparian owner has the right of receiving the water of a stream in its original state of purity, and can take action to stop the discharge of any polluting matter into the stream, unless the person causing such a discharge has acquired a right by prescription or otherwise. In the Rivers Pollution Prevention Act, 1876, such pollutions are dealt

TABLE IX.

SAMPLES FROM WORKS WHERE AMMONIA IS RECOVERED FROM GAS LIQUOR.

(Results expressed in parts per 100,000.)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Tar Oils.			Sulphur.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Alkalinity (as $CaCO_3$).
		Total.	Ash.	Total.	Ash	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Acidic.	Basic.	Total.	As Sulphate.	In other forms	As Sulphocyanide.		
Gas liquor from coke ovens . . .	665·2	3·2	0·4	662·0	44·0	672 00	4·50	49·00	440·0	200 0	640·0	13·4	187·0	...	665 0	...
Gas liquor from coke ovens (including devil water) . .	602·5	3·5	1·2	599·0	33·0	747·60		69 40	16·0	187·5	203·5	14·4	254·8	30 7	713·5	...
Gas liquor from gasworks . . .	1508·0	very small		1508·0	25·6	2520·00	31·70	156·80	380·0	110·0	490·0	15·3	1248·2	...	2816·0	...
Devil water from coke ovens . . .	14·0	2·0	0·0	12·0	0·0	...	...	...	...	...	...	..	...	trace	1520·0	...
Devil water from coke ovens . . .	4·0	very small		4·0	0·8	123·20	4·75	14·70	395·0	33·0	433·0	nil	99·1	19·8	1002·0	...
Devil water from gasworks . . .	7·6	very small		7·6	2·0	1·64	0·25	1·65	277·0	17·0	294·0	nil	4·0	...	550·0	...
Devil water from gasworks . . .	79·2	9·2	6·2	70·0	26·6	40·60	...	..	...	...	...	12·4	12·4	...	565·0	...

TABLE IX.—*continued.*

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Tar Oils.			Sulphur.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Alkalinity (as $CaCO_3$).
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Acidic.	Basic.	Total.	As Sulphate.	In other forms.	As Sulphocyanide.		
Spent liquor from coke ovens . . .	523·0	11·0	4·6	512·0	96·0	104·44	2·04	9·26	30·0	15·2	45·2	12·5	29·6	...	194·0	...
Do. . .	963·0	223·0	186·7	740·0	536·0	109·76	1·97	9·13	129·0	6·0	135·0	8·3	50·0	13·3	378·3	450·5
Do. . .	591·0	6·0	3·2	585·0	232·0	89·04	4·82	8·68	12·0	2·0	14·0	17·7	62·5	...	312·0	...
Spent liquor from gas-works . . .	1871·8	33·3	22·7	1838·0	854·0	144·00	15·70	61·00	574·0	trace	574·0	19·7	200·4	...	366·0	...
Do. . .	25·4	2·4	1·2	23·0	18·0	5·74	...	0·70	2·8	1·6	4·4	1·7	0·6	...	74·1	...
Water from benzol stills . . .	...	...	...	...	...	711·20	...	...	...	...	...	nil	353·3	...	655·0	...
Do. . .	38·8	1·8	0·7	37·0	5·2	893·40	...	...	...	...	...	1·0	88·2	9·9	236·3	...
Gas liquor from shale-oil works . .	86·0	very small		86·0	6·0	1106·00	trace	nil	146·0	18·0	164·0	3·6	22·7	...	140·0	...
Spent liquor from shale-oil works . .	340·1	2·1	1·2	338·0	6·0	81·20	0·60	4·20	30·0	18·0	48·0	62·2	47·2	...	54·4	...
Effluent filtered through pit heap at shale-oil works . .	699·0	very small		699·0	486·0	0·00	0·01	...	...	...	nil	98·2	nil	...	0·1	...

with in the same way as those caused by any other manufacturing process. The Public Health Act, 1875, is much more drastic; Section 68, following the Gasworks Clauses Act, 1847, says that:

> "Any person engaged in the manufacture of gas who—(1) Causes or suffers to be brought or to flow into any stream reservoir aqueduct pond, or place for water, or into any drain or pipe communicating therewith, any washing or other substance produced in making or supplying gas; or, (2) Wilfully does any act connected with the making or supplying of gas whereby the water in any such stream reservoir aqueduct pond or place for water is fouled, shall forfeit for every such offence the sum of two hundred pounds, and, after the expiration of twenty-four hours' notice from the local authority or the person to whom the water belongs in that behalf, a further sum of twenty pounds for every day during which the offence is continued or during the continuance of the act whereby the water is fouled. . . ."

The law with regard to the admission of this class of refuse to sewers, although not so emphatic, is such as to render it very doubtful if the admission could be enforced. Although Section 7 of the Rivers Pollution Prevention Act, 1876, provides that facilities shall be given by a Local Authority for draining trade refuse into public sewers, the provisoes are such as almost certainly to take away any such right thus to dispose of chemical refuse. Besides, Section 17 of the Public Health Acts (Amendment) Act, 1890, which is an adoptive Act, contains the following:—

> "Every person who turns or permits to enter into any sewer of a local authority or any drain connecting therewith—
>
> "(*a*) Any chemical refuse, . . . which, either alone or in combination with the sewage, causes a nuisance or is dangerous or injurious to health, shall be liable to a penalty not exceeding ten pounds, and to a daily penalty not exceeding five pounds."

To comply fully with the law on the subject, therefore, it would seem to be necessary to prevent entirely the discharge of any spent gas liquor into a stream or sewer; and it is towards this result that most successful efforts have been made, and, as will appear later, with profit to the colliery proprietors.

As a guide to the amount of spent gas liquor produced in the distillation of coal, the following figures, estimated on the dry coal converted into coke in coke ovens, may be given:—

Water of combustion	4 to 6	per cent.,	or	9 to 14	gallons per ton.
Moisture in coal	10 to 15	,,	,,	22 to 33	,, ,,
Water from scrubbers	15 to 20	,,	,,	33 to 45	,, ,,
Steam for distillation	8 to 10	,,	,,	18 to 22	,, ,,
Lime water added to stills	10	,,	,,	22	,, ,,
Total	47 to 61	,,	,,	104 to 136	,, ,,

Thus a battery of forty coke ovens, turning into coke some 200 tons of coal per day, will roughly yield 25,000 gallons of spent gas liquor per day.

It has been pointed out that by using water from the scrubbers in the hydraulic main and by resorting to the counter-current principle in washing the gases, the volume of gas liquor can be greatly reduced. The spent gas liquor can to some extent be used up for preparing the milk of lime which is introduced into the stills and for filling the seal pots of the scrubbers and tar extractors.

The purification of this kind of refuse has been a problem difficult to solve. It is easy, by the use of simple settling tanks, to get rid of suspended solids, but these, although objectionable, are innocuous compared with the matters in solution. It has been shown by Gilbert J. Fowler, D.Sc., F.I.C. (*Journ. Soc. Chem. Ind.*, 1911, vol. 30, pp. 174, 180, 181), at Broughton Road Gasworks, Manchester, and at Frizinghall Chemical Works, Bradford, that the liquid when diluted is amenable to treatment on biological filters, such as are described in Chapter XI. p. 269. He has constructed a percolating filter of somewhat coarse material, 6 to 9 feet deep, and prepared it either by using material which had previously formed part of a sewage filter, or by ripening the filter by the application of a weak sewage until nitrification was induced. To such a filter he has applied the spent liquor from gasworks, clarified by settlement and diluted to ten times its original volume, either with clean water or with the filter effluent, at the rate of 100 gallons of the dilute liquid per square yard per day. The results of this treatment are shown in Table X., where it will be seen that the process effects a very marked reduction in the oxygen-absorbed figure, while the sulphocyanides and phenols are also greatly reduced; but it must be borne in mind in considering the first series of analyses that part of the apparent purification is due to dilution with water.

Dr Fowler has succeeded in isolating a special organism which apparently has the power of oxidising phenol (*Proc. Roy. Soc.*, 1911, B. 562, and *Journ. Soc. Chem. Ind.*, 1911, vol. 30, p. 174). Bacteriological examination shows that although, as might be expected, the spent liquor coming from the stills is sterile, the effluent from the filter teems with bacterial life, sometimes containing as many as 320,000 bacteria per c.c.

The cost of carrying out this process is considerable, 2 to 3 cubic yards of filtering material being required for every 10 gallons of the crude refuse produced daily. Thus, for a battery of forty ovens yielding 25,000 gallons of spent liquor daily, over half an acre of filter 6 to 9 feet deep would be required, and even after this purification, which is greater than has been attained by any other process, the liquid would still deleteriously affect a pure stream of small volume. It could, however, be used for many colliery purposes, such as coke quenching and coal washing.

Other methods of purification have been tried or suggested at various times. At Sutton and other places where spent gas liquor was discharged into the sewers and found to interfere with the treatment of the sewage, Mr Radcliffe of Barnet introduced a method of precipitation with sulphate of copper in order to eliminate the sulphocyanides. In this process the refuse is settled to deposit suspended lime salts and is then treated with a solution of sulphur dioxide and calcium bisulphite made from the gases leaving the saturator. A solution of copper sulphate is next added to bring about a precipitation of cuprous sulphocyanide, which can be

TABLE X.

TREATMENT OF SPENT GAS LIQUOR ON PERCOLATING FILTERS.

(Results expressed in parts per 100,000.)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Sulphocyanides (in terms of Sulphur).	Hardness (as $CaCO_3$).		
		Total.	Ash.	Total.	Ash.	Nitric and Nitrous.	Ammoniacal.	Albuminoid (Wanklyn).			Total.	Permt.	Tempy.
Crude refuse from gasworks .	2947·1	6·10	4·30	2941·0	2001·8	...	5·45	13·50	874·0	67·65	1690·0	1468·0	222·0
*Diluted refuse being treated on percolating filter . . .	154·8	1·60	0·72	153·2	116·2	...	0·32	0·32	29·8	4·62	103·0	103·0	0·0
Percolating filter effluent .	176·9	0·10	0·10	176·8	140·0	...	1·47	0·11	3 9	1·19	101·5	95·7	5·8
Crude refuse	...	...	...	...	...	...	27·70	18·50	738·0	..	...	...	...
†Diluted refuse . . .	...	...	...	...	...	0·90	4·75	0·98	30·0	present	...	...	...
Filter effluent. . . .	...	. .	...	...	...	1·44	5·08	0·59	12·2	present	...	...	...
Crude refuse	2414·0	...	...	2414·0	1540·0	nil	16·80	...	664·0	...	1484·0	1484·0	0·0
†Diluted refuse . . .	740·0	...	...	740·0	536·0	nil	24·10	...	66·8	...	552·5	552·5	0·0
Filter effluent	464·0	...	...	464·0	318·0	nil	19·60	...	17·6	...	371·0	332·7	38·3

* Diluted with stream water.

† Diluted with filter effluent.

recovered by settlement, dried, and sold. This process reduces the amount of phenols present and produces an effluent which apparently does not interfere with the treatment of sewage with which it may be mixed; it is said, in fact, to favour the growth of bacterial life. The effluent cannot be considered sufficiently pure to be discharged into a stream, but Mr Radcliffe claims that it might be used at a colliery for such purposes as coal washing and coke quenching.

At Cambuslang Gasworks another patent plant by Mr Radcliffe has been introduced in order to purify the gas liquor so far that it can be received into the public sewer and dealt with at proposed sewage works. The spent gas liquor is allowed to trickle down through a tower, up which the waste gases which escape from the saturator are allowed to pass. The effect of this treatment is stated to be "to precipitate free lime in solution, to decompose phenylate and cresylate of lime and cyanogen compounds, also the precipitation of soluble organic matter in solution." Into a lower and separate compartment of the same tower steam and air are blown to aid oxidation and to carry off some of the volatile impurities. The waste gases from the upper compartment are carried on to an ordinary oxide purifier, whilst the vapours from the lower compartment are conducted to a fire, where they are destroyed. The spent liquor after being exposed to the gases is conveyed to settling tanks, where the lime and suspended solids are removed, and passed through coke strainers to the sewer. It is claimed that the resulting purified effluent when added to sewage in a proportion not exceeding 15 per cent. increases bacterial growth, thus assisting the purification of the sewage. It is also claimed that at coke ovens such an effluent, like that from Mr Radcliffe's other process, may be used for quenching coke, and some of it for steam raising, gas scrubbing, and other purposes.

A modification of this plant has been erected by Mr Radcliffe at Enfield Gasworks and at Wellington Gasworks, the effluents being also discharged into the sewers. In this modified process acid is added to the liquor as it enters the aerating compartment in sufficient proportion to set free the sulphocyanic acid present. This is carried over by the injected air and condensed in a receiver. Mr Radcliffe claims that by this method he can remove all solids in suspension, all free lime, all hydrocyanic acid, 70 per cent. of the sulphocyanides and 60 per cent. of the solids in solution, and can reduce the oxygen-absorbed figure by 75 per cent.

J. Grossmann, Ph.D., F.I.C., in considering methods for preventing a discharge of spent gas liquor from the manufacture of sulphate of ammonia, suggests (*Journ. Soc. Chem. Ind.*, 1906, vol. 25, p. 411) that the gas liquor should be distilled without lime and the effluent from the still re-used in the scrubbers until it becomes sufficiently charged with fixed ammonium salts and cyanogen compounds to render their recovery profitable. He has also suggested the use of dilute sulphuric acid instead of water in the scrubbers and the circulation of the acidified sulphate of

TABLE X.

TREATMENT OF SPENT GAS LIQUOR ON PERCOLATING FILTERS.

(Results expressed in parts per 100,000.)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Sulphocyanides (in terms of Sulphur).	Hardness (as $CaCO_3$).		
		Total.	Ash.	Total.	Ash.	Nitric and Nitrous.	Ammoniacal.	Albuminoid (Wanklyn).			Total.	Permt.	Tempy.
Crude refuse from gasworks .	2947·1	6·10	4·30	2941·0	2001·8	...	5·45	13·50	874·0	67·65	1690·0	1468·0	222·0
*Diluted refuse being treated on percolating filter . . .	154·8	1·60	0·72	153·2	116·2	...	0·32	0·32	29·8	4·62	103·0	103·0	0·0
Percolating filter effluent .	176·9	0·10	0·10	176·8	140·0	...	1·47	0·11	3·9	1·19	101·5	95·7	5·8
Crude refuse	...	...	...	...	...	...	27·70	18·50	738·0	..	...	...	...
†Diluted refuse . . .	...	...	...	...	...	0·90	4·75	0·98	30·0	present	...	...	...
Filter effluent. . . .	...	..	...	...	...	1·44	5·08	0·59	12·2	present	...	...	...
Crude refuse	2414·0	...	...	2414·0	1540·0	nil	16·80	...	664·0	...	1484·0	1484·0	0·0
†Diluted refuse . . .	740·0	...	...	740·0	536·0	nil	24·10	...	66·8	...	552·5	552·5	0·0
Filter effluent. . . .	464·0	...	...	464·0	318·0	nil	19·60	...	17·6	...	371·0	332·7	38·3

* Diluted with stream water.

† Diluted with filter effluent.

and then other means of disposal must be adopted. The spent liquor is used, mixed with other water, for washing coal, but has sometimes caused trouble in certain types of washer by frothing. At many collieries the refuse is used for slaking or quenching the hot coke as it is discharged from the ovens. Objections to this course have at times been suggested. It has been said that this use of the liquor makes the outer surface of the coke dark in colour, spoils its bloom, and so depreciates its value; but after careful inquiry the general opinion is found to be that it makes no difference to the users whether the coke has been quenched with spent gas liquor or with clean water. Any objections which formerly were taken to the dark colour were sentimental and are now rapidly disappearing. The same objections were in fact formerly raised with regard to any coke produced in patent coke ovens, since it is not so bright and lustrous as that produced in the old beehive ovens.

Another suggested objection is, so far as the public are concerned, a much more serious one: it is that such a liquor, when evaporated into the atmosphere, may be injurious not only to human beings but to other animals, and to vegetation. This would apply with equal force to any method by which the refuse is evaporated, whether on the hot coke, on a burning spoil-bank, or in a special furnace, but careful inquiries have failed to show any effect either upon the health of the workers on the spot or upon that of the inhabitants of the country around. The chemical refuse so evaporated produces, no doubt, a certain amount of objectionable smell, but this is altogether insignificant when compared with that produced by the fumes of steam and smoke which are discharged from every battery of coke ovens, or from a burning spoil-bank.

Direct evaporation of the chemical refuse in furnaces of special construction has been adopted in several instances. This method of disposal has been in use at some of the blast furnaces in Lanarkshire and in Ayrshire for many years, the fuel being in these cases some of the surplus gas from the furnaces, of which there is always a considerable quantity wasted. It has also been brought into use at two collieries, one in the West Riding of Yorkshire and one in Derbyshire, at both of which the refuse is settled for the removal of the suspended lime, and then sprayed into hot furnaces, where it is evaporated and escapes by the chimney, leaving behind only a quantity of sludge, which is carted to the spoil-bank.

At the West Riding colliery the furnaces have been built by the Simplex Coke Oven Co., Ltd., and are so constructed that they can be heated either with gas from the coke ovens or by means of solid fuel. If coal had to be bought for the purpose, the process would certainly be a very expensive one, although the spraying renders the evaporation more rapid than would be the case in an ordinary boiler; but at a colliery with a coke oven plant there is always an ample supply of waste fuel as well as the surplus gas from the ovens.

In this case 14,300 gallons of ammoniacal liquor are made daily and distilled in the ordinary way, so that there are probably 18,000 gallons of waste liquor to be dealt with, and three evaporating furnaces have been brought into use, of which one at least is always held in reserve. These, including a special chimney 80 feet in height, spraying apparatus, and all necessary accessories, cost £1400 to build.

Formerly waste tar and coke breeze supplemented by gas from the ovens were used as fuel, but now the furnaces are heated entirely by gas. As a result of this change, together with some improvements in spraying the gas liquor, only one furnace is now required, whereas two used to be constantly at work. The labour bill is also much reduced, as one man is now employed, and only for half his time, whereas two were formerly fully occupied. When the waste breeze and tar were being used as fuel the smoke from the chimney was at times considerable, but now nothing is seen but a cloud of steam. Formerly, the furnaces had to be relined at a cost of £20 each once in six months, and wholly rebuilt every twelve months at a cost of £80 each; now, they have been worked under the new system for six months and show no sign of deterioration.

The arrangement of the plant is shown in Fig. 4. Each furnace is 15 feet square and 15 feet high, made of red brick strengthened by iron bars. It is divided into four compartments by dwarf walls rising to within 2 feet of the roof. It was at first lined with firebrick, but experience has shown that red brick stands better, and now it seems that large slabs of sandstone are more durable still. The joints are the first to give way, and they are therefore made as few and as fine as possible. The great secret in preserving the lining of the furnace has been found to be to keep it constantly wetted, and the method of spraying has been improved with this object. The liquor is delivered through the roof of the furnace through four $1\frac{1}{2}$-inch iron pipes, one for each compartment. Each pipe has a blind end, and the liquor escapes in a spray through sixteen horizontal slits ($1\frac{1}{2}$ inches long and $\frac{1}{12}$ inch wide) made by a saw. The gas is fed through four $2\frac{1}{2}$-inch mains into that part of the furnace above the top of the dwarf walls, and the vapour escapes by the chimney flue, which is near the level of the floor.

The liquor as it comes from the ammonia still is passed through two settling tanks having a total capacity equal to half a day's flow, and from these it passes into a sump, from which it is pumped by a Worthington pump. The pumping arrangements are in duplicate, so that one set is always available should the other break down. The liquor is pumped into the furnaces through the above-mentioned pipes and is blown through the slits in a fine spray by the aid of a jet of steam. This steam is supplied to the furnace by a 1-inch pipe and injected into each delivery pipe through a $\frac{3}{16}$-inch nozzle. By this arrangement the liquor is sprayed over the whole of the walls of the furnace, keeping them constantly wetted. The bulk is evaporated and escapes up the chimney, while the residual liquor with the solids resulting from the evaporation falls to the floor of the furnace and is drained back into the settling tanks. The sludge removed from these tanks, which includes the settled lime as well as the deposit from the evaporation process, amounts altogether to 25 tons per month. As the furnace is liable to crack owing to the intense heat, some of the residual liquor occasionally escapes into the foundations, and it has been found necessary to intercept it by a deep drain alongside the furnace on the lower side, and to convey it to a sump, from which it is pumped back to the settling tanks.

At these works the supply of gas is practically unlimited, and no attempt has been made to economise in its use. It is estimated that about 200,000 cubic feet per day are used, the gas having a calorific value of 450 B.T.U., but if some form of Bunsen burner were introduced this quantity could be reduced by 40 or 50 per cent.

At the Derbyshire colliery 50,000 gallons of waste liquor are dealt with daily, and the total cost of the plant, including a special chimney and all the necessary accessories, was £1538. The fuel used is blast-furnace gas and waste gas from the ovens.

In certain cases in Lanarkshire, in connection with blast furnaces, the refuse has been used for feeding steam boilers, but in these cases the gas liquor has been distilled without the aid of lime. The method is not an advisable one for dealing with ordinary gas liquor, unless it is subjected to some preliminary treatment to remove the lime, and considerably diluted with clean water.

The latest developments in coke oven chemical works seem likely to render superfluous all the foregoing methods of dealing with the gas liquor. At the least, they will reduce the volume and alter the character of the refuse to be dealt with, making the problem much easier. In December 1908, Mr A. Victor Kochs read a paper before the Midland Institute of Mining, Civil, and Mechanical Engineers ("The Recovery of Bye-products from the Distillation of Coal, with Special Reference to the Koppers' New Process," *Trans. Inst. M.E.*, 1908, vol. 36, p. 326), describing the Koppers' new process for the recovery of ammonia from coke oven gas. Instead of extracting the ammonia by washing the gas with water, it is obtained by passing the gas directly through sulphuric acid in the saturator. The hot gas leaving the hydraulic main is cooled to a temperature of about 30° C. and passed through a tar extractor, so that the tar and gas liquor are condensed. The gas is then heated to a temperature of 65° C. and passed at this temperature into the saturator, from which it passes on to the ovens, reaching them at a temperature of 40° C.

The bulk of the ammonia is thus taken up by the acid in the saturator directly from the gas, and there is no water used for scrubbing the gas and therefore no ammoniacal liquor from this source. But there is still the gas liquor produced from the original moisture of the coal and from the products of combustion, from which the ammonia must be distilled by the aid of live steam and lime. The figures given at one colliery are as follows:—The amount of wet coal turned into coke per day is 740 tons, containing 12·5 per cent. moisture (88 tons); the water produced in the combustion of the coal is 4·36 per cent. (38 tons). The total possible quantity of ammoniacal liquor is therefore 126 tons; the steam necessary for distillation 31 tons; the moisture carried on in the gas 10 tons; giving therefore a total quantity of waste liquor of 126 + 31 - 10 = 147 tons. This amounts to 22 per cent. by weight of the dry coal coked, or 50 gallons per ton. It was stated that in the old process, where the gas is scrubbed, a ton of water per oven per day is required for scrubbing, or in this case 120 tons per day, which would require another 30 tons of steam for its distillation, and would thus increase the amount of waste liquor by 150 tons. By the new process therefore the amount of waste liquor would seem to be decreased by over 50 per cent.

If benzol is to be recovered, the gas as it passes from the saturator must again be cooled to 25° or 30° C. and scrubbed with creosote. If it is required for gas-engines or for lighting purposes it must in some cases be purified by the removal of sulphuretted hydrogen.

The liquid produced by this secondary cooling is not at all like that discharged from an ammonia still; when freed from particles of tar, which easily separate on standing, it is a pale yellow liquid and, as it contains no lime, it can be used, mixed with other water, for coal washing or coke quenching, or can be evaporated by spraying it into the chimney of the ovens, in which way it is stated that as much as one ton of liquor per oven per day can easily be dealt with. Even in an extreme case, the amount would not be more than this. Analyses of such liquids are given in Table XI.

A further development has been made by the Otto-Hilgenstock Coke Oven Company, Ltd. In their new plant (see Fig. 5) the hot gases from the hydraulic main pass straight into the sulphate house, the tar which has condensed in the gas-main being collected in a tar-trap. The rest of the tar is extracted from the gases by a somewhat peculiar method, hot tar being sprayed into the gas in a vessel called a "tar-spray." A little water separates with the tar and is pumped into the hydraulic main. Any excess contains fixed salts of ammonia, and, being small in amount, can ultimately be run into the saturator with the acid, or can be evaporated for the recovery of ammonium chloride. The gases leaving the tar-spray are still at a temperature above the dew-point, and the water vapour is therefore kept from condensing; and without any further cooling the gases are passed through the acid in the saturator and thence directly to the ovens. A small amount of tar appears in the form of a frothy scum on the acid in the saturator, but this is easily skimmed off. The gases leaving the saturator have a temperature of 85° C., but, in passing along the gas-main, they become somewhat cooled, and this causes the condensation of a little refuse water.

TABLE XI.

REFUSE CONDENSED FROM GAS AFTER DIRECT RECOVERY PROCESSES.

(Results expressed in parts per 100,000.)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Sulphur.			Phenol.	Hydrocyanic Acid (HCN).
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).		Total.	As Sulphate.	As Sulphocyanide.		
From gas-mains in Otto-Hilgenstock process. (No benzol recovered) . . .	14·1	0·9	0·1	13·2	0·8	17·50	1·75	5·13	126·1	7·11	1·48	2·64	...	9·52
,, ,, . . .	65·1	0·5	0·0	64·6	3·6	12·99	0·56	2·83	378·2	13·29	5·77	1·98		1·40
From first cooling tower in Otto-Hilgenstock process. (Benzol recovered)	14·8	0·8	...	14·0	6·8	17·20	0·84	3·45	495·2	14·28	trace	3·96	...	2·24
From second cooling tower in Otto-Hilgenstock process. (Benzol recovered)	20·2	0·2	...	20·0	11·6	47·50	0·12	2·83	668·2	41·35	trace	5·41	...	13·66
From serpentine cooler in Simon-Carves process. (Benzol recovered)	58·2	48·6	0·2	9·6	2·8	21·10	...	...	...	10·70	1·00	4·90	394·6	8·70

This refuse, like that produced by cooling the gas in Koppers' process, is not like that from an ammonia still, inasmuch as it contains no lime, nor, because of the high temperature of the gas, does it contain any sulphuretted hydrogen (see Table XI.). It can therefore be used, diluted with other water, for any of the ordinary purposes of the colliery, or, being small in amount, can easily be evaporated by spraying it into the chimney of the ovens. In a properly constructed plant, where the gas-mains are short and well protected, there is no need for the condensation of any liquid refuse whatever, and all the moisture can be passed on with the gases to the ovens.

As in Koppers' process, if the gas is used in gas-engines, or if benzol is recovered, the gas must be cooled down to a temperature of 25° or 30° C., at which most of its water vapour condenses as liquid refuse. In one case where this system is in use and 400 tons of coal are coked daily in sixty regenerative ovens, the gas is cooled for use in a gas-engine, and the amount of liquid refuse produced by condensation is said to be about 1 ton per oven per day, or 13,440 gallons in all.

At another plant, where a direct recovery process is adopted, erected by the Simon-Carves Bye-Product Coke-Oven Construction and Working Company, Limited, there are twenty-eight ovens coking daily 175 tons of coal containing 11·5 per cent. of moisture, and the total amount of liquid refuse is 25 tons per day, 2 tons of which are deposited along with the tar, and the remainder in the process of cooling the gas for benzol recovery. At this place there is also a sulphate plant on the old system, and the waste liquid from the direct process is pumped to the scrubbers of the old plant.

A full description of the Otto-Hilgenstock plant is given in an article in *The Iron and Coal Trades' Review* ("The Direct Recovery of Tar and Ammonia from Hot Gases," *Iron and Coal Trades' Review*, 1909, vol. 79, p. 959), and Fig. 5 shows the whole of the necessary chemical works. Those who are acquainted with the ordinary type of chemical works will see at once how comparatively simple this new type is. The hot gases pass straight into the sulphate house, where a new recovery plant is shown in two series, one of which acts merely as an emergency reserve. They enter the tar-sprays T_1 and T_2, where, through the cleansing action of the spray, they are freed from their tarry matter at a temperature above the dew-point, and whence, without any further cooling, they are forced by the exhauster E through the acid in the saturator S, and relieved of their ammonia. The precipitated sulphate is ejected on to the draining table D, and dried in the centrifugal C. The hot gases leave the saturator, still retaining all their moisture in the form of steam, and return uncooled to be used for heating the ovens. Coolers and benzol scrubbers can easily be added to such a plant and are shown in dotted lines.

Similar direct recovery processes are now being advocated by most of the coke-oven firms, and they are even being introduced in ordinary gasworks (see *The Local Government Officer and Contractor*, 1910, vol. 9, p. 241, and *Forty-eighth Annual Report of the Chief Inspector of Alkali Works*, 1911, p. 113), mainly because they are economical and more profitable than the old processes.

The economies effected by the new processes are many. The chemical plant is simplified by leaving out the water scrubbers and, in the Otto-Hilgenstock and Simon-Carves plants, the coolers and ammonia stills; the yield of sulphate is said to be increased by 5 to 10 per cent., and this is easily explained by the simplification of the plant and the consequent fewer opportunities for loss of ammonia. In the old process there is some loss by leakage, but more especially because the ammonia in the gas is not completely absorbed by the water in the scrubbers, and because that in the gas liquor is not completely yielded up in the process of distillation. The quality of the sulphate is also improved, and less acid is required for the absorption of the ammonia, inasmuch as the fixed ammonia salts distilled from the coal do not require to be decomposed with lime and again fixed with acid. Further, the quantity of water required is very greatly reduced, the steam and lime necessary for the ammonia stills in the old system are not required, and there is a considerable saving in the initial cost of the works, as well as in the upkeep. So great are the economies that in several instances an old-fashioned plant is being scrapped in favour of a new one.

TABLE XII.

WATER FROM GAS-HOLDER TANKS.

(*Results expressed in parts per 100,000.*)

Period in Tank.	Total Solids dried at 100° C.		Nitrogen		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Sulphur.			Hydrocyanic Acid.	Ether Extract.
	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).		Total.	Sulphate.	Sulphocyanide.		
3 weeks	34·4	25·2	0·18	0·04	0·80	1·5	1·5	..	.	1·2
15 years	31·0	20·4	1·40	0·20	2·40	2·3	2·3	..	..	1·6
25 to 30 years	37·2	21·9	7·28	0·55	7·82	4·09	2·58	0·67	3·11	3·1

In some of these newer processes, such as those of Burkheiser, Feld, and Fabri, means are adopted for the recovery of sulphur from the gas and its utilisation in the production of the sulphate of ammonia, but from none of these further processes is there any liquid refuse discharged.

Storing Gas.—Where gas is stored in gas-holders, these invariably have a water seal, the water in which, being exposed to the action of the gas, absorbs various impurities. If kept up for any length of time it may become a very polluting liquid (see analyses in Table XII.). Precautions should be taken to prevent the discharge of such liquids to a stream, and this is no difficult matter, as there need be no flow of water through the water seal, but only the addition of a little from time to time to make up for loss by evaporation. The rain which falls on the surface of the gas-holder is usually sufficient for this purpose, and any excess should be prevented from reaching a stream.

Manufacture of Power Gas.—There has recently been a great development in the manufacture of gas specially suited for internal combustion gas-engines and for firing furnaces and boilers. For the present purpose the gas plant used may be divided into two classes: those of the Mond type, in which bituminous fuel is used and ammonia is recovered; and the suction-gas producers, where the fuel used is either anthracite or coke. A lecture on Producer Gas by H. A. Humphrey, A.M.I.C.E., given under the auspices of the London Chamber of Commerce (Higher Commercial Education Pamphlet Series, No. 11), describes concisely those of the former class, and gives several illustrations of the plant used.

By passing a heated mixture of air and steam through the glowing fuel, a highly inflammable gas is produced, containing hydrogen, carbon monoxide, and methane, as the main combustible constituents, and carbon dioxide and nitrogen as non-combustible. Owing to the large amount of steam which is introduced along with the air, a comparatively low temperature is maintained, and consequently ammonia is produced and passes on with the gas, which also contains dust, tarry impurities, and cyanogen compounds.

The impure gas, issuing from the producer (see Fig. 5A) at a temperature of about 500° C., is passed through a tubular regenerator, where it parts with much of its heat to the mixture of air and steam entering the producer. The gas is then passed through a mechanical washer, which is the name applied to a long rectangular iron chamber fitted with revolving dashers which rotate and fill the whole chamber with water-spray. The partly cooled gas is here further cooled and washed, and, moreover, much of its remaining sensible heat is transformed into latent heat by the evaporation of some of the water. The gas, laden with its burden of steam, and now at a temperature of 85° C., then traverses, from bottom to top, a large lead-lined tower, called the acid tower, down which a stream of acid sulphate of ammonia liquor is always descending. This liquor contains about 2 per cent. of free sulphuric acid, which takes up the ammonia contained in the gas, converting it into sulphate of ammonia. To make the action continuous some free acid is always being added and some sulphate of ammonia liquor removed from the plant for evaporation and the production of solid sulphate of ammonia for the market. The gas and steam next pass downwards to the inlet of the "gas-cooling tower," in ascending which the mixture meets a stream of cold water which cleans and cools the gas and condenses the water vapour it contains. From the cooling tower it enters the gas-mains at a temperature of 70° C., and if the mains are of any great length a considerable amount of liquor is condensed as the gas cools in them.

At the other end of the plant air is driven in at a pressure equal to 25 inches of water, and passed upwards through an air-heating tower, where it meets a spray of the water which has been heated in the gas-cooling tower. The incoming air thus becomes heated and saturated with water vapour, and after the addition of more steam the mixture of air and steam, at a temperature of 85° C., is led to the tubular regenerator, where it abstracts heat from the gas leaving the producer, raising it to a temperature over 200° C., and finally, in the Mond plant, is further heated by its passage through an annular space surrounding the producer on its downward course to the fire grate. The fire grate is at the bottom of the producer, which is sealed by means of water.

The sulphate of ammonia liquor removed from the acid tower is evaporated either in an open vessel or in a closed still under reduced pressure, to crystallise out the salt. In the former case the evaporated water escapes into the air, while in the latter it has to be condensed with large volumes of cold water.

The possible sources of pollution from a plant of this kind are therefore:

(*a*) The water seal under the producer
(*b*) The mechanical washer.
(*c*) The gas-cooling tower.
(*d*) The air-heating tower.
(*e*) The still for evaporating the ammonia liquor.
(*f*) The gas-mains.
(*g*) The scrubbers, if the gas is used in gas-engines.

The liquids from all these sources are somewhat similar as regards their polluting character to ordinary spent gas liquor. They contain sulphur and tarry compounds, but no lime, and they readily absorb oxygen.

Since the process as a whole is one which consumes considerable quantities of water—one authority states that a ton and a half of steam is used up for every ton of fuel—there is no real need to discharge any liquid refuse.

(*a*) In the water seal there is a constant evaporation going on, and any overflow is the result of carelessness. The ashes which accumulate and have to be removed from time to time are saturated with water, and care must be taken to place them in such a position that the water may drain back into the seal.

(*b*) In the mechanical washer there is also a continuous evaporation of the water, but the tarry sludge which collects has to be removed from time to time, and here also care must be taken to prevent the escape of liquid draining from it. The sludge consists of particles of fuel mixed with tarry matter, and can be burnt in boiler furnaces.

(*c*) and (*d*) The water in the gas-cooling and air-heating towers should be kept constantly circulating, that which is heated in the former being used to warm the air in the latter; none of it should be allowed to escape, but, on the contrary, as has been shown, much is absorbed by the air in the air-heating tower. When insufficient provision is made for cooling the gas, difficulties may arise in its use, and the water from the air-heating tower may be too hot to reduce the temperature sufficiently. To avoid this the water, after leaving the air-heating tower, may either be passed over a water cooler, or returned to a reservoir, from which it is pumped back to the gas-cooling tower, and in either case much water is lost by evaporation. Another way of surmounting this difficulty is to provide another gas-cooling tower with a constantly circulating supply of cold water. Whichever method is adopted, the water should be kept in a closed circuit and none allowed to escape.

(*e*) In most cases the principal source of refuse is the condensation of the vapour from the still in which the sulphate of ammonia liquor is evaporated. When this is a vacuum still a jet condenser is generally used to condense the vapour, and the condensing water, of which 25 lbs. are required for every 1 lb. of vapour, becomes impregnated with tarry matters and sulphur and cyanogen compounds evaporated from the liquor (see Table XIII.). There seems no reason why a closed or surface condenser should not be used, and in that case only the condensed vapour would require to be dealt with. It would be small in amount and could be used in the water seal or mechanical washer. If the jet condenser is preferred, then the condensing water can be passed over a cooler and re-used, the amount of condensed vapour being more than balanced by the evaporation taking place on the surface of the cooler. By constant re-use this condensing water may become so impregnated with phenols as to make their recovery profitable. At some works the sulphate of ammonia liquor is evaporated in an open vessel, so that the vapour escapes through the chimney flue, and in such cases no liquid refuse is produced from this part of the process.

The discharge of liquid refuse from this part of the process could also be wholly avoided by the adoption of a direct process for the recovery of ammonia, such as has been brought into use in connection with coke ovens, as described on pp. 39 and 42. This would be advantageous not only in avoiding the discharge of waste water, but also in greatly simplifying and cheapening the apparatus required. The lead-lined acid tower, which is costly both to construct and to keep in repair, would be unnecessary, as also would be the evaporating plant and the large volume of water required in connection with it. The gas could be passed through tar extractors, such as the Otto-Hilgenstock tar spray or the Simon-Carves centrifugal

TABLE XIII.

WASTE WATERS FROM GAS PRODUCER PLANTS.

(Results expressed in parts per 100,000.)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.)		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Alkalinity (in terms of Na_2CO_3).	Acidity (in terms of H_2SO_4).	Hardness (in terms of $CaCO_3$)			Sulphur.			Cyanides (in terms of HCN).	Tar Oils.			Tarry Matter adhering to bottle.
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Total.	Filtrate.			Total.	Permanent.	Temporary.	Total.	As Sulphate.	As Sulphocyanide.		Acidic.	Basic.	Neutral.	
Water from producer seal	222·1	15·7	9·8	206·4	159·0	0·90	0·13	0·47	12·50	11·80	23·3	..	106·0	106·0	..	25·8	24·7	0·44	0·03	1·0	1·0	0·8	..
Liquid from mechanical washer . .	32,119·4	114·4	22·9	32,005·0	1118·8	8762·0	22·2	97·75	1190·0	1126·0	84·8	..	3365·0	2837·5	527·5	1531·7	1353·0	9·9	..	64·0	20·0	182·0	..
Liquid from gas-cooling and air-heating towers . . .	1,511·7	2·5	0·04	1,509·2	75·4	235·2	5·00	10·85	678·0	675·0	..	35·3	131·6	125·6	6·0	133·5	130·4	..	..	47·0	45·0	54·0	19·5
Condensing water after use in sulphate of ammonia plant .	75·5	14·3	2·6	61·2	23·2	5·88	0·42	0·57	57·08	46·57	5·3	..	44·3	16·3	28·0	9·25	7·91	..	..	26·0*	4·7	..	..
Liquid condensed in gas-mains . . .	671·9	1·1	0·0	670·8	39·4	120·4	1·16	4·03	318·2	312·2	..	9·8	251·2	80·6	170·6	70·38	66·1	..	..	5·4	8·0	57·2	262·5
Water after being used for scrubbing gas for use in gas-engines .	455·6	0·6	0·1	455·0	31·0	72·1	1·77	4·6	323·3	321·3	..	7·35	236·0	78·0	158·0	40·56	37·26	..	..	13·4	10·6	59·4	113·4

* Including neutral tar oils.

apparatus, and then directly through strong sulphuric acid in a saturator, in which the solid sulphate of ammonia would be deposited.

(*f*) The gas as it leaves the producer plant still contains a considerable proportion of water vapour, and where the distributing mains are long and exposed, this is condensed to a very polluting gas liquor, containing sulphur compounds and tarry matters and some ammonia (see Tables XI. and XIII.). This liquor is not great in amount, and can be used either to feed the water seal or mechanical washer, or mixed with the condensing water, especially if this is to be treated for the recovery of phenols.

(*g*) The water from scrubbers (see Table XIII.) can be used in the mechanical washer or water seal.

TABLE XIV.

REFUSE FROM SUCTION-GAS PLANT.

(*Results expressed in parts per 100,000.*)

Fuel Used.	Total Solids.	Solids in Suspension (dried at 100° C)		Solids in Solution (dried at 100° C.).		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Sulphocyanides (in terms of S).	Hydrocyanic Acid (as HCN).
		Total.	Ash.	Total.	Ash.			
Anthracite .	65·0	16·0	5·2	49·0	36·0	6·30	nil	1·26
,, .	73·4	38·8	12·9	34·6	11·6	8·71	trace	0·50
,, .	54·7	24·5	10·8	30·2	12·6	7·42	trace	0·56
,, .	30·3	18·5	5·7	11·8	8·0	6·00	0·18	0·36
Coke . .	44·8	3·4	1·6	41·4	30·6	2·04	trace	0·13
,, . .	36·8	3·8	1·2	33·0	15·2	2·60	nil	0·24
,, . .	48·8	very small		48·8	32·6	2·81	nil	0·26
,, . .	21·6	1·8	1·7	19·8	11·9	2·56	trace	trace

Considerable quantities of tar are distilled along with the gas, and if care is not taken this is liable to escape along with the water used in the various processes. The tar collects in the water of the mechanical washer, in that from the gas-cooling and acid towers, and in the condensings from the gas-mains, but if these liquids are allowed to stand the tar separates and may either be skimmed off or retained by the provision of suitable tar-traps. The recovered tar may either be sold to the tar distiller or burnt under the boilers of the works, but in the latter case special appliances will have to be adopted for burning it.

In conclusion, therefore, it may be urged that there is no need to discharge any refuse from a plant of this kind.

Suction-gas Plant.—In the second division of gas producers, in which non-bituminous fuel is used, the apparatus is greatly simplified. The principle adopted in the producer is almost invariably the same, air and water vapour being drawn through the incandescent fuel and the gas thus produced being cleansed by passing upwards through scrubbers filled with coke, kept constantly moistened by a water spray. There are usually two ways in which polluting discharges may arise: the overflow from a water seal on the gas-main between the producer and the scrubber, and the escape of the water which has passed through the scrubber. The waste water coming from such a plant is fortunately not large. Its character varies greatly, according to the nature of the fuel used (see Table XIV.). When coke is used the liquid produced is only slightly polluting in character, and, if settled sufficiently to remove small particles of coke, can usually be discharged to a stream without detriment. If anthracite is the fuel used, the resulting waste water is more polluting, containing appreciable amounts of tarry matters and cyanogen compounds. It is not fit to be discharged to a stream, but could be mixed with domestic sewage for treatment without causing any difficulty. Where, therefore, no sewer is available, coke should always be used as a fuel in preference to anthracite.

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CHAPTER IV.

GRAIN WASHING, MALTING, BREWING, AND DISTILLING.

Nature of waste waters — Grain washing — Washers— Screens — Further treatment— Malting — Intermittent and continuous steep — Biological filtration — Brewing— Various processes—Treatment on land—Mixed with sewage—Highfield Brewery, Shepley — Distilling — Processes — Pot ale — Spent lees — Experiments of Royal Commission of 1898—American experience—Summary—Bibliography.

THE waste waters from all these processes are somewhat similar in composition, in that they contain in solution and suspension large quantities of organic matters belonging to the classes of carbohydrates and proteids. All of them are liable to undergo acid fermentation, and in doing so to give off very offensive smells. They are very liable, moreover, to induce a profuse growth of fungus in any stream into which they may be discharged. Similar means of purification can be used for each of them, and where several of these processes are carried on at the same premises, as is often the case, the different kinds of refuse can be mixed and treated together. As, however, there are works where only one of the processes is in operation, it will be better to deal with the character and treatment of each kind of refuse separately.

Grain Washing.—Grain is washed for two purposes: in the first place, to cleanse it from sand, clay, light and imperfect grains, chaff, and dust, impurities with which much foreign grain, especially that from the East, is found to be contaminated; and, in the second place, much foreign wheat is too dry to be properly milled into flour, and the washing process serves also to "condition" it, that is, to bring the moisture up to the amount necessary for proper milling (8 to 10 per cent.).

Many of the impurities can be removed from the grain before washing by passing it through suitable screening and winnowing apparatus, and the polluting character of the discharge from the following washing can thus be greatly lessened.

The apparatus used in grain washing is very simple in principle, and usually consists of a tank in which the grain is agitated in a current of water and from which it is passed by means of a worm conveyor or similar contrivance. Clean water is allowed to enter in such a way that the grain leaving the tank meets the stream of clean water, while the dirty water carrying the lighter impurities overflows at the further end. The heavier impurities settle to the bottom of the tank, and must be removed from time to time. In the case of Indian wheat these heavier impurities consist in great part of small pebbles, which have a market value for sale to keepers of poultry. The grain leaving the tank carries with it a good deal of dirty water, which is removed by means of a centrifugal machine, and discharged along with the water which escapes by the tank overflow.

A patent washer of this type, constructed by Messrs Henry Simon, Ltd., Manchester, is shown in Fig. 6. The machine consists essentially of a water tank, divided into several compartments, and two inclined conveying worms, the casing of both worms being made of perforated brass. For the thorough washing of hard wheats the dry grain is fed into the bottom of the longer worm, which is immersed in the water. This worm carries the wheat up into a small hopper, from which it is fed on to a stream of water flowing over a finely perforated sheet of brass. By the action of a large plunger at the side, pulsations of the water are produced, and thus the wheat is thoroughly agitated in the water while it is flowing over the perforated sheet. At the end of the brass sheet there is a gap filled up with coarse pebbles followed by a low weir. The stones and clay balls, from their weight, find their way down through the pebbles into a box in the bottom of the tank,

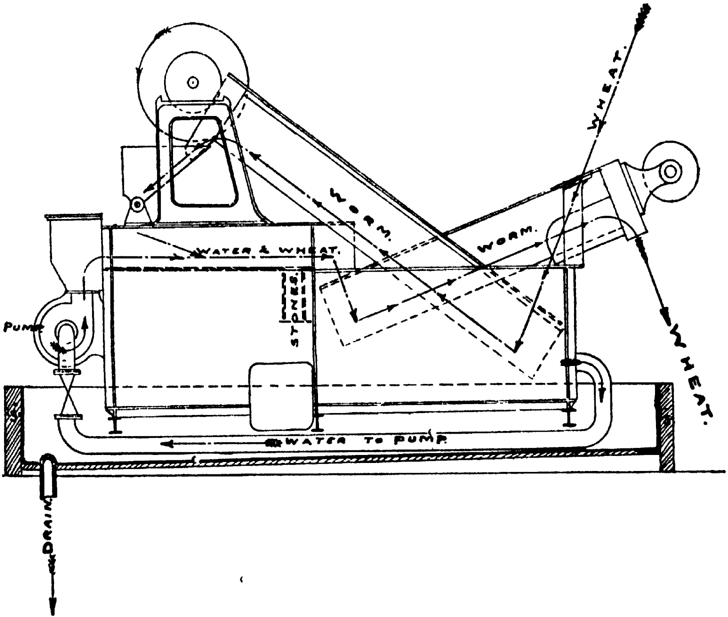

FIG. 6.—Grain-washing Machine. (Messrs Henry Simon, Ltd., Manchester.)

whereas the wheat itself is carried by the water over the weir, and so down into the foot of the second worm, from the upper end of which it is delivered into the whizzer to be dried. Over this worm a row of water sprays is fixed so as to rinse the wheat finally with clean water. Softer wheats, not requiring so thorough a soaking, are fed into the hopper already mentioned so as to miss the first soaking. The clean water is sprayed upon the wheat leaving the washer and passes through the perforated casing of the worm into the tank beneath. From this it is pumped to meet the wheat as it falls from the hopper, and then passes along with the wheat to the second worm. A constant circulation of the water is thus kept up. An overflow is provided for any excess water, but most of that which escapes from the washer is carried into the whizzer along with the wheat.

In another kind of washer the grain is fed into a hopper, where it is agitated by a stream of clean water which enters at the bottom and overflows at the top, carrying the grain with it. Both grain and water are then run into a centrifugal drier, from which the dirty water continuously escapes.

The quantity of water used naturally varies with the amount and character of the impurities present in the grain, and these depend largely on the kind of grain. English wheat is generally so clean that some millers do not think it requires washing. Indian wheat, on the other hand, often contains as much as 4 per cent. of dirt which can be removed by screening, and probably an equal amount which is removed in the washing. These varieties of wheat are at the extremes of the scale as regards dirt, whilst other varieties, such as Canadian and Russian, are intermediate. In one mill, where practically all kinds of wheat are washed, and where half the water leaving the washer is constantly pumped back for re-use, the average consumption of water amounts to 24 gallons for each quarter of grain washed. In another mill, where the wheat washed is almost entirely foreign, it is estimated that 30 gallons of water are used for each quarter of grain, although here also there is a continuous circulation and re-use of water. At a third mill, where the supply of water is practically unlimited and none is re-used, nearly 100 gallons per quarter are used.

The waste water from the washer is brown and muddy, containing considerable amounts of clay and sand in suspension, and carrying with it chaff and light and badly formed grains. It contains in solution, as analysis shows (see Table XV.), considerable amounts of nitrogenous organic matter, and it is nearly always slightly acid in reaction, the acidity being due to acid fermentation of the organic matters extracted from the grain.

The treatment of this waste water is not a difficult matter. It should first be thoroughly sieved or screened, and there are several forms of screening plant now on the market. They differ mainly in the arrangement of the sieve and in the devices adopted for keeping it clean. In the

TABLE XV.

GRAIN-WASHING REFUSE.

(Results expressed in parts per 100,000.)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Acidity (in terms of Lactic Acid).	Hardness.			Matter in Solution.				Coarse Solids removed before Analysis.
														Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).			Total.	Perm.	Temp.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).		
Crude . .	293·1	162·6	55·5	130·5	84·5	0·29	2·10	4·03	16·14	10·3	38·6	25·4	15·2	nil	0·39	0·85	7·78	51·43
Sieved . .	271·1	158·7	47·3	112·4	71·6	0·27	1·74	3·54	16·50	10·8	42·2	26·9	15·3	nil	0·31	0·78	7·40	3·34
Crude . .	661·0	468·2	154·8	192·8	88·8	...	...	...	29·50	...	...	...	..	...	...	...	11·21	...
Sieved . .	417·1	251·5	106·8	165·6	91·2	...	..	...	21·11	...	...	...	.	...	...	..	8·87	...
Crude . .	322·8	192·4	81·8	130·4	73·6	0·50	1·97	5·56	29·85	18·0	35·1	17·4	17·7	0·20	0·57	2·00	13·10	20·96
Crude . .	301·9	114·9	37·4	187·0	119·2	nil	1·80	2·36	18·10	nil	71·9	52·3	19·6	nil	0·36	0·93	10·46	63·2

plant (Fig. 7) of Messrs. Higginbottom & Co., Ltd., Liverpool, the sieve is in the form of an inclined cylinder, into the upper end of which the dirty water is fed. The cylinder revolves and thus throws the screenings to the lower end, whilst the water escapes through the meshes. The screenings are then passed between rollers to remove the excess of moisture. In this apparatus the screen is cleaned by means of jets of water. Fig. 8 illustrates the form of apparatus made by Messrs Henry Simon, Ltd., Manchester. In this plant the sieve, which usually has 70 meshes and 70 perforations per lineal inch, is fixed in an inclined position and kept clean

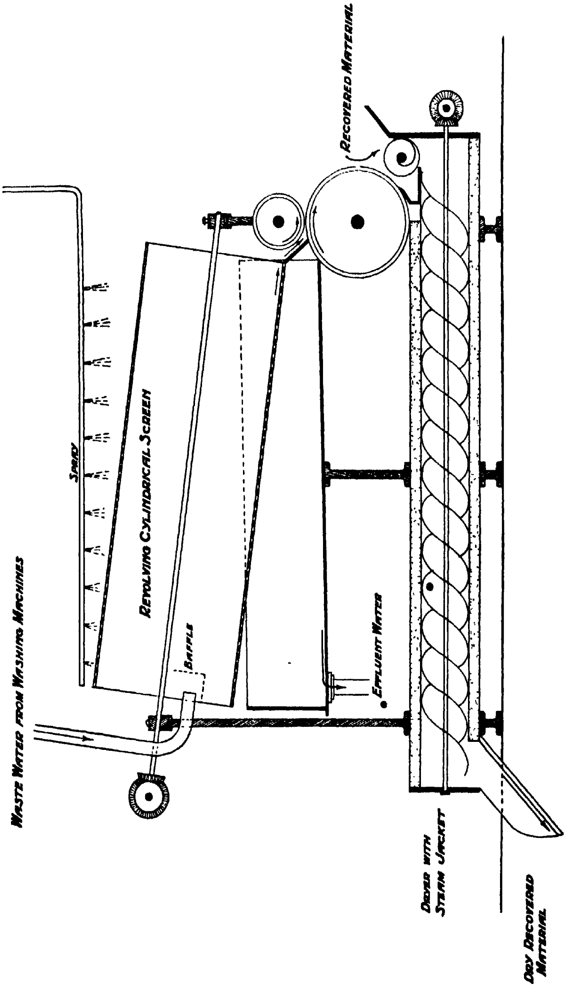

Fig. 7.—Screening Plant for Grain-washing Refuse. (Messrs Higginbottom & Co., Ltd., Liverpool.)

by means of travelling brushes. A plant which has proved very effective for the removal of fibres from dyewaters might also be adapted to the treatment of this kind of waste water. It is made by the Longwood Engineering Co., Ltd., Longwood, near Huddersfield, and is illustrated in Fig. 41.

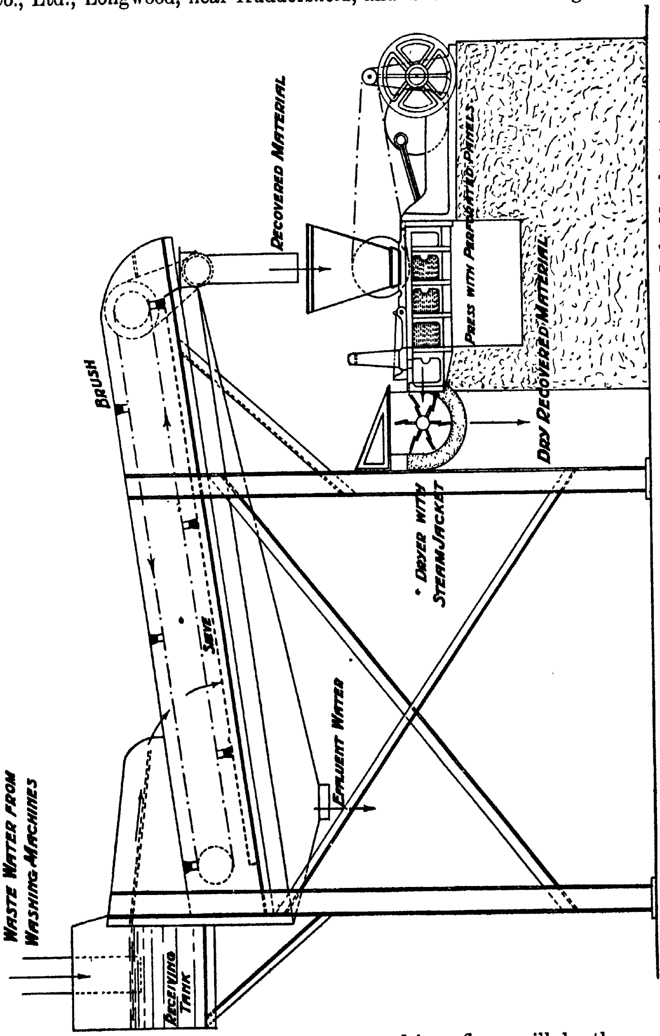

Fig. 8.—Screening Plant for Grain-washing Refuse. (Messrs Henry Simon, Ltd., Manchester.)

The "beeswing" or screenings recovered in a flour mill by the use of such a plant vary in amount from one-fifth to one-third per cent. of the wheat washed. They are either mixed with the general offal from the mill or sold separately as poultry food, and yield a considerable return. In one mill, where 250 quarters of wheat are washed daily, and where the total cost of the screening plant amounted to £250, the value of the screenings amounts to more than £100 per annum.

The water escaping from such a screening apparatus is still a polluting liquid (see analyses in Table XV.). It should be passed through settling tanks to deposit the fine clay and sand, and the addition of a little lime assists in bringing down the fine particles in suspension and causes also precipitation of some of the organic matters in solution. The effluent after this treatment, if turned into a large body of running water, will have little appreciable effect. If, however, a higher degree of purification is required, as for instance if the stream lower down is used as a source of water supply, it may be obtained by effective filtration.

Sometimes the effluent from the screening apparatus is passed direct through high-pressure filters (see p. 269), such as are manufactured by Messrs Bell Bros., Ravensthorpe, Yorks, Messrs Hawksley, Wild & Co. Ltd., Sheffield, or F. Candy, Westminster, London, and afterwards either re-used for grain washing, or used for feeding boilers.

Malting.—The whole of the grain used in brewing and much of that used in distilling is malted before use, and from this process there is a considerable discharge of polluted water. The operation is described by the Royal Commission on Sewage Disposal, 1898 (Sixth Report, p. 4), as follows:—

> "In this operation the barley is steeped in water in order to clean and soften it, so that when removed to the malting floor it may germinate. Two methods of steeping are in use. In one, the barley is allowed to soak in tanks in two or three successive lots of water for a total period of about sixty hours; in the other, water is allowed to flow into and out of the tank containing the barley, for the same length of time. The waste steep water which is produced by the former method is highly charged with organic matter—the first portion of it especially being a very foul-smelling and polluting liquid. In continuous steeping the waste steep liquor is organically weaker, but there is necessarily a much larger volume of it. By the first method about 8 to 10 gallons of waste steep water are produced for each bushel of barley soaked. No records are available as to the quantity of waste steep water produced by continuous steeping, but probably 30 to 40 gallons per bushel of barley would be approximately correct. It is a grey or brown foul-smelling liquid, and it contains the dirt, dust, and grit which were mixed with the barley, together with certain soluble mineral salts and organic bodies, and colouring matter from the barley husks. The following are typical analyses of steep waters produced by the two methods:—

TABLE XVI.

	Continuous Process.	Quiescent Soaking.
	Parts per 100,000.	Parts per 100,000.
Ammoniacal nitrogen . . .	0·13	0·58
Albuminoid nitrogen	0·45	2·24
Oxygen absorbed in four hours from $\frac{N}{8}$ permanganate at 27° C. . .	30·00	86·00
Dissolved oxygen taken up from water for complete oxidation . . .	(say) 260*	(say) 700–800*

* "These are estimates based on the analysis of a limed steep water."

Analyses of the discharges from a maltkiln where the barley received three steepings, in each of which 36 gallons of water per quarter of barley were used, are given in Table XVII., in which are also given two analyses of the first steeping water from another maltkiln.

This kind of refuse, like that from grain washing, can be purified without any great difficulty. Probably the best method is irrigation on a suitable area of grass land, but other methods are available. If suspended solids are screened out, and the liquid is passed in a fresh state on to a percolating filter such as will be described in connection with the treatment of brewing refuse (see pp. 64 and 269), it can be purified to any required degree. The screened liquid, indeed, can be passed into running streams, when these are of considerable volume, without producing any perceptible deterioration in them, but if discharged into sluggish streams or stagnant shallow ponds it is liable to undergo very offensive putrefaction.

Table XVII.

BARLEY-STEEPING WATERS.

(*Results expressed in parts per 100,000*).

Steep No.	1.	2.	3.	1.	1.
Total solids (dried at 100° C.)	305·60	143·76	112·91	474·36	396·90
Solids in suspension. Total	5·20	1·36	0·11	2·96	7·50
,, ,, ,, Ash	0·40	0·16	0·08	0·64	1·70
Solids in solution. Total	300·4	142·4	112·8	471·4	389·4
,, ,, ,, Ash	171·0	77·0	62·0	233·4	186·0
Chlorides (in term of NaCl)	45·0	17·0	16·5	81·0	55·0
Nitrogen, ammoniacal	0·48	0·13	0·02	0·99	1·20
,, albuminoid (Wanklyn)	2·47	1·22	0·76	4·80	5·07
,, organic (Kjeldahl)	4·41	2·07	1·47	11·06	9·40
Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	44·00	25·40	21·44	39·92	52·32
Acidity (in terms of lactic acid)	32·4	28·8	27·0	104·1	126·0
Hardness (in terms of $CaCO_3$). Total	74·2	51·5	51·5	82·9	103·0
,, ,, ,, Permt.	44·3	37·1	37·1	78·1	81·4
,, ,, ,, Tempy.	29·9	14·4	14·4	4·8	21·6

By means of biological filtration of the fresh refuse through a single percolating filter it has been found possible in laboratory experiments to effect a 90 per cent. purification, judging on the oxygen-absorbed figure, and to produce a well-nitrified non-putrescible effluent. The Royal Commission, 1898 (Sixth Report, Appendix II. p. 31), obtained similar results. They used a filter 12·25 feet in diameter and 10·5 feet deep, containing 45 cubic yards of coarse clinker. The filter was fitted with a small revolving distributor fed automatically from a 5-gallon tipper. The steep water was treated with a small quantity of lime, settled, and applied to the filter at the rate of 25 gallons per cubic yard per day continuously throughout the whole of the twenty-four hours. The effluent obtained was uniformly good, and it was found that it produced no bad effects when discharged into a channel carrying an equal amount of clean water. It will be noted that in this case the steep water was limed, but in laboratory experiments the liming was found inadvisable, as it caused the liquid to putrefy rapidly and become very offensive.

Brewing.—Brewery refuse causes very marked pollution when discharged into a stream. It contains many suspended solids, such as spent hops and grains, much dissolved organic matter from the materials used in brewing, and in addition carries with it many living ferments and moulds, so that immediately it is discharged it begins to decompose, and in this decomposition it gives off a peculiar and most offensive smell.

A brief description of the process of brewing will best show the sources of the polluting discharges. The brewer who buys his malt first puts it through a process of dressing to get rid of dust and germs. There should be no liquid refuse from this process, but in some breweries it is said to be the practice to transform the dust into mud by spraying it with water and to wash it down the drains. The waste water thus produced must be highly charged with organic matter in suspension, and in many cases will also contain considerable quantities of arsenic, which is nearly always present in the dust of malt.

The dressed malt is passed into large "mash tuns," where hot water is sprinkled upon it in order to extract all the soluble matter, the watery extract, known as "wort," being drained from the mash tuns into a large storage vessel, the "underback" or "wort receiver," or directly into a copper.

When the mashing is completed the wort is run into a copper, where it is boiled and where hops are added, and when the boiling and infusion of hops is completed, the wort is run into a "hopback," where the liquid is drained off from the hops and from which it is passed through a cooler and refrigerator into the fermenting vessels. In the cooler, which is a shallow vessel for exposing a large surface of the wort, many albuminoid substances settle as the temperature of the liquid is reduced.

In the fermenting vessels yeast is added and the fermentation is allowed to go on until the beer is ready to put into casks, which are usually filled directly from the fermenting vessels, but sometimes from a special "working or settling back" into which the contents of the fermenting vessels are first poured.

The grains or spent malt from the mash tuns are removed to some place of storage from which they can be distributed as required, being generally sold for feeding cows and pigs; and as they are quite saturated with water when first removed from the mash tuns, a considerable quantity of water drains away from them, and this contains sufficient organic matter to give rise to decomposition. A similar liquid drains from the spent hops when they are removed from the copper or hopback.

From the fermenting vessels, while the fermentation is going on, large quantities of yeast froth up and are allowed to overflow. This yeast is sometimes stored for sale or for re-use, or is sometimes passed through filter presses, which express the liquid and leave the yeast in the form of a cake. It may be noted that where 100 lbs. of yeast are added to a fermenting vessel, 600 lbs. are often obtained as the result of fermentation. Sometimes the yeast is washed down the brewery drains, and when it is pressed the watery liquid draining from the presses is allowed to escape by the same channels. These yeasty liquids are particularly liable to undergo rapid decomposition, accompanied by the formation of acetic, lactic, and butyric acids.

In the cellars where the casks are filled they are allowed to remain until some further fermentation has taken place in the beer, and froth and beer are spilled on the cellar floor and allowed to escape into the drains. In the cellars also "finings" of gelatine are added to the casks of beer, and the washings of the casks of finings are poured into the drains.

The direct discharges of waste waters from the brewing processes are therefore the drainage from the grains and hops, the yeast or the liquid pressed from it, and the beer spilled from the casks. These, although highly impregnated with organic matter, and in the latter two cases crowded with germs of fermentation, are only small in amount compared with the total quantity of waste water discharged from a brewery.

Successful brewing, being dependent upon a well-regulated process of fermentation, can only be carried on under conditions of the utmost cleanliness. Dirty vessels or dirty premises, by favouring the growth of putrefactive and other undesirable bacteria, are certain to interfere with the production of good beer. The whole of a brewer's apparatus and premises must therefore be frequently and thoroughly cleansed, and the bulk of the waste waters discharged from the brewery are those which have been used for washing purposes. The mash tun, the underback or wort receiver, the copper, the hopback, the cooler and refrigerator, the fermenting vessels, the yeast backs, the casks, the floors and walls of the various rooms, are all frequently swilled with cold or hot water, which carries away with it some part of the organic matters which have been contained in the various vessels. In cleansing the copper and the wort mains—copper pipes for conveying the wort to and from the copper—soda or potash is used, and in cleansing the casks, soda, permanganate of potash, quicklime, or calcium bisulphite is frequently used.

Perhaps the greatest source of pollution is the cask washing. The casks as they return to the brewery often contain quantities of sour beer and hops, a handful of the latter being usually added to each cask of beer before it is bunged up, and these are washed out when the cask is cleansed. At breweries where beer is bottled there is a similar, but smaller, discharge from the washing of the bottles.

In addition to all these polluting liquids there is also at every brewery a large discharge of quite pure water which has been used in the refrigerators and for "attemperating." The refrigerator is an arrangement of metal pipes exposing a large surface, on the outside of which the wort in its passage from the cooler to the fermenting vessels is exposed in thin layers, while through the inside a stream of clean cold water is constantly running. Brewing can only be carried on properly at a moderate and equable temperature, and in each fermenting vessel there is usually a coil of pipes through which a stream of cold "attemperating" water is kept running for the purpose of keeping the temperature of the vessel contents within bounds. These refrigerating and attemperating waters are thus free from pollution, and there is no need to discharge them along with the trade refuse. In many cases they are conveyed to a tank from which they are pumped for re-use, and where this is not done they should be discharged by a separate outlet to the nearest stream.

It has been found a matter of great difficulty to obtain anything like reliable figures of the quantity of water used by brewers. One authority states that for every barrel of beer brewed (excluding the water used for cooling and attemperating), about eight barrels of water are required, that is, that for every barrel of beer there are seven barrels of dirty water. In several breweries where the water supply is passed through a meter the quantity of refuse has been found to be between 500 and 600 gallons per 100 gallons of beer brewed. In one case, however, the brewer states that he uses only 100 gallons of water for cask washing and 25 gallons for washing down the brewing plant for every 100 gallons of beer brewed.

Table XVIII. gives the analyses of most of these kinds of waste waters and of average samples of the mixed refuse. It will be seen that many of the samples were acid in reaction. The amounts of acid present must not be taken as being there when the samples were fresh, for the acid fermentation was, no doubt, proceeding during the interval between the taking of the samples and their analysis.

The treatment of brewery refuse is not always a problem easy of solution. In the case of a small brewery in the country very effective purification can be attained by irrigation of the refuse upon old pasture, and this is the method adopted by many brewers. By a little attention to the proper distribution of the liquids they may be dealt with very effectively and with advantage to the growth of grass. In cases where sufficient areas of land are available all the refuse is absorbed, and in others where an effluent escapes over the surface or through the soil it is so purified as to produce no appreciable effect in a stream. In all cases before passing the refuse over the land it ought to be passed through screens and settling tanks to remove suspended solids.

The treatment of brewery refuse by irrigation upon land on a large scale is not an easy matter. At Burton-on-Trent, where the daily flow of sewage amounts to 5,300,000 gallons, of which 66 per cent. is brewery refuse, although 613 acres of arable land are used for its treatment, the results are not always satisfactory, and there have sometimes been com-

BREWERY REFUSE.

(Results expressed in parts per 100,000.)

Sample of	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Hardness (as $CaCO_3$).			Acidity (as Lactic Acid).
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).		Total.	Permt.	Tempy.	
Drainage from grains (mash tun)	294·6	2·6	0·6	292·0	28·0	0·36	4·16	6·96	21·7	22·8	22·8	nil	15·3
Drainage from grains (mash tun)	1297·0	25·0	4·2	1272·0	46·0	0·65	large	18·39	74·5	..	...	...	61·2
Drainage from grains (mash tun)	384·0	150·0	11·6	234·0	53·0	0·10	8·18	13·06	34·5	...	...	...	neutral
Drainage from hops	3420·0	*1108·0	574·0	2312·0	146·0	1·60	large	94·72	347·8		..	...	126·0
Washings from hopback	270·2	*49·2	9·8	221·0	66·0	nil	2·60	5·80	22·9	39·2	12·0	27·2	4·5
Swillings from copper	62·0	12·0	3·6	50·0	27·0	0·13	0·59	1·25	4·7	..	...	...	slight
Swillings from copper	317·4	*100·4	47·0	217·0	90·0	0·65	3·14	6·37	79·8	78·4	59·4	19·0	4·5
Swillings from copper	316·6	*38·6	23·0	278·0	253·0	0·10	0·83	1·67	9·9	...	...	...	**227·9
Washings of the cooler	498·6	41·6	8·0	457·0	51·0	0·40	..	5·48	36·9	70·8	59·4	11·4	35·1
Washings of the cooler	3046·0	36·0	1·6	3010·0	70·0	0·60	large	18·16	143·7	...	...	...	43·2
Swillings from fermenting vats	5558·0	4684·0	1158·0	874·0	82·0	2·52	large	290·10	399·4	..	..	...	104·4
Swillings from fermenting vats	747·0	427·0	34·0	320·0	124·0	0·50	27·28	40·60	74·7	118·7	50·2	68·5	34·2
Swillings from fermenting vats	5886·0	4310·0	216·0	1576·0	182·0	39·55	large	317·12	684·8	...	...	...	210·0
Swillings from fermenting vats	908·0	618·0	34·0	290·0	78·0	0·40	43·40	55·10	93·0	...	...	...	slight
Yeast vessel washings	1266·0	784·0	18·4	482·0	142·0	1·30	50·50	84·70	113·0	..	...	...	54·0
Yeast vessel washings	1094·0	842·0	60·0	252·0	72·0	0·60	28·50	76·10	109·0	...	...	...	19·8
Cellar swillings	267·0	*170·0	105·0	97·0	47·0	0·20	1·10	3·59	19·8	50·2	39·2	11·0	neutral
Barrel washings	252·9	62·9	5·3	190·0	96·0	0·36	3·98	8·53	29·3	75·2	65·7	9·5	7·65
Barrel washings	371·0	99·0	3·2	272·0	90·0	0·40	13·00	16·90	63·5	...	...	...	9·0
Barrel washings	123·0	41·0	17·0	82·0	38·0	nil	2·02	3·73	20·5	...	...	...	slight
Bottle washings	57·2	2·2	0·9	55·0	36·0	0·03	0·11	0·28	1·1	34·4	29·7	4·7	neutral
Bottle washings	162·6	13·6	2·4	149·0	57·0	0·04	1·61	2·73	22·0	...	...	...	neutral
Bottle washings	65·6	5·6	0·8	60·0	39·0	trace	0·34	0·89	7·7	...	...	...	sl.alk.
Combined waste	178·0	20·0	3·3	158·0	70·0	0·26	2·85	3·90	26·3	...	...	...	14·4
Combined waste	429·6	*171·6	51·6	258·0	174·0	0·85	6·12	12·49	38·6	73·6	34·0	39·6	9·0

* After straining through wire gauze to remove hops.

** Alkalinity (as Na_2CO_3).

plaints of offensive smells. Here the sewage is limed at the rate of 40 grains per gallon, but it is neither screened nor settled before being applied to the land.

Frequently, however, a brewer has not a sufficient area of land upon which to irrigate his refuse, and then resort must be had to more artificial methods. The ordinary methods of chemical precipitation followed by straining filters cannot be relied upon to produce a good result, and recourse must be had to biological treatment, but the biological purification of such a liquid is by no means so easy as that of domestic sewage. One factor to be reckoned with, is the presence of large quantities of spent hops, spent grains, yeast and corks, which, however, can easily be caught by the provision of arrangements for effective screening, and by placing scumboards to catch floating matters on any settling tanks which may be used. Another factor raises greater difficulties. Owing to acetic, butyric, and lactic acid fermentation of the organic matters the refuse is either strongly acid as it is discharged or almost immediately becomes so, and while in this acid condition is not amenable to the action of those other ferments and organisms which bring about the purification of ordinary sewage. This has been well pointed out by W. Naylor, F.C.S., in his book on *Trades' Waste* (Chapter V.), and by other observers.

Mr Naylor advocated the addition to the refuse of a quantity of domestic sewage or sewage sludge, the mixture being dealt with in a septic tank, and by this treatment, he stated, the ordinary changes which take place in sewage are induced and prevent the acid fermentation. This is true to some extent, but this inhibiting effect of the sewage cannot be depended on for any length of time, and works constructed and used on this principle at Hook Norton Brewery, Banbury, and at Fountains Free Brewery, Blackburn, although for some time giving good results, failed to do so continuously. It is also a serious drawback to this method that the septic tank effluent has a most objectionable smell. Another method of overcoming the acid fermentation is by treating the refuse with lime. This neutralises any acidity, but unless added in very large quantity does not kill the ferments, and the liquid when allowed to stand soon becomes acid again. Because of this rapid acid fermentation the treatment of brewery refuse in contact beds is not successful, as the length of time necessary for filling the bed and allowing it to remain full gives too much opportunity for the action of the acid-forming bacteria; and at times the whole bed seems to become charged with the bacteria, a state of matters difficult to remedy except by removing the filtering material and constructing the bed afresh.

When the refuse is kept from becoming acid, and has its suspended solids removed, it can be thoroughly purified by treatment on continuous filters, although more repeated filtrations may be required to produce a satisfactory effluent than would be needed for ordinary sewage.

Such an installation, carried out by Mr J. T. Chambers for Messrs Seth

Senior & Sons at Highfield Brewery, Shepley, near Huddersfield, is shown in Fig. 9. At this brewery the refuse comes from all the processes incidental to the brewing of beer and porter, except that there is no barley-steeping water, the malting being done elsewhere. It averages about 10,000 gallons a day, or about thrice the volume of beer brewed. It first passes through a small sump in the brewery yard, 6 feet square and 4½ feet deep, where grosser solids are retained. They are removed every few days, and amount to nearly a ton a week.

From this the refuse is conveyed to three stone-built settling tanks, each of 12,000 gallons capacity, and fitted with floating arms for decanting the liquid, and sludge valves for discharging the solids which settle as sludge. A day's discharge of refuse practically fills one tank, and to this is added about 140 lbs. of dry lime, or 100 grains a gallon, which is thrown by shovel over the surface of the tank contents. The liquid thus neutralised is allowed to stand overnight to allow of the settlement of the solids, and thus clarified is decanted by means of the floating arm. The method of adding the lime is an extravagant one, and probably half the amount would be sufficient if it were added as milk of lime.

The tank effluent is conveyed to a circular filter, to which it is applied by means of an automatic revolving distributor of the usual type (Adams'). The filter is 30 feet in diameter or 78 square yards in area, and is 6½ feet deep. It is composed chiefly of broken stone, the pieces varying in size from 3-inch cubes at the bottom to ½-inch at the top, with a covering layer of coal about 1 foot in depth, and of ½-inch gauge. It is built upon a concrete floor and underdrained by numerous tile drains. The rate of feeding this filter is regulated by the outlet valve of the settling tank. It would no doubt be a better arrangement if the liquid were applied in intermittent doses by means of a tipper.

The effluent from the first filter passes through a catchpit 6 feet by 6 feet and 2½ feet deep, and is conveyed to a second filter 160 square yards in area and 6 feet deep. This is filled with coke in sizes varying from 3-inch to ½-inch cubes, covered by a layer of sods, broken into pieces of some 4 inches square, to foster nitrification. It is underdrained with ordinary field drain pipes. The liquid is applied to it by means of spraying jets, which are fixed 6 feet above the surface of the material. The effluent from this filter is discharged to the stream.

The drain from the first filter to the second is about 300 yards long, and in this there is a considerable deposit of gelatinous fungus (*Oospora lactis*), which clogs the jets and thus interferes with the proper distribution of the liquid on the second filter. A catchpit should be provided on the drain, with a bottom valve by means of which this fungus could be flushed out on to the surface of a field.

The sludge from the settling tanks is discharged on to three sludge beds, each about 23 square yards in area, formed of 2 feet of stone and cinders, with underdrains discharging to the surface of adjacent grass land, where the liquid is absorbed. Each tank is sludged on an average once in three weeks, and then contains about 3 inches of liquid sludge (say 6 cubic yards). About five loads of air-dried sludge are produced per month.

The total cost of these works, exclusive of the site, is estimated at £1050. The labour required, including the sludging, takes half a man's time, and costs 10s. 6d. a week, and about a third of a ton of lime is used weekly. Allowing 10 per cent. on the outlay for interest and depreciation, these figures give 11·6 pence per 1000 gallons as the cost of treatment.

Analyses of the refuse and effluents are given in Table XIX. The effluent is discharged into a very small stream, Shepley Dyke, the volume of which in dry weather is less than the volume of the effluent. Formerly the bed of this stream was covered with fungus (chiefly *Sphærotilus natans* with filaments of *Crenothrix polyspora*), and its water had a very offensive smell of brewery waste. Neither the smell nor the fungus has quite disappeared, but both are now little noticeable.

It will be noticed in the analyses of the final effluents that practically no nitrates are present, and this may be taken as a sign that the purification has not proceeded so far as might be wished. In the course of some experiments (*Journ. Royal San. Inst.*, 1904, vol. 25, part 3, p. 574) it was found that by finally passing a similar filter effluent through garden soil nitrates were produced, and it was because of this that the final filter at Shepley was covered with sods. Dr Calmette (*Recherches*, vol. 3, p. 74, and vol. 6, p. 208) has concluded from his experiments that in the purification of liquids such as these the carbohydrates present greatly retard, if they do not prevent, nitrification, but the experiments on the purification of barley-steeping water and of brewery refuse, which have been mentioned above, show that it is certainly possible to bring about nitrification.

Messrs Clark & Adams have gone carefully into this question, and have shown (*Journ. Ind. Eng. Chem.*, 1912, vol. 4, p. 272) that such substances as sugar, molasses, butyric acid, alcohol, and wool-scouring refuse, bodies rich in carbon, have a strong effect in checking nitrification, and may even stop it when present in sufficient proportion. They find that even when nitrification is checked the purification effected as judged by the albuminoid ammonia and oxygen-absorbed figures is not materially lessened, but that when ammonium chloride is added to the liquid under treatment this check in nitrification does not take place.

Brewery refuse, unfortunately, yields no bye-products worth recovery, so there is little prospect of the brewer's recouping himself for the expense of treatment. Much yeast is certainly allowed to run to waste which might be kept back and re-used or sold, and there is a small demand for the crude refuse by manufacturers of fine wire, who use it for wire steeping, no doubt on account of its acidity; but the quantity which can thus be disposed of is very small.

Distilling.—The Royal Commission on Sewage Disposal, 1898, have

TABLE XIX.

ANALYSES OF SAMPLES TAKEN AT HIGHFIELD BREWERY, SHEPLEY (SETH SENIOR & SONS).

(*Results expressed in parts per 100,000.*)

Sample of	Total. Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.				Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Acidity (as Lactic Acid).	Alkalinity (as Na_2CO_3).	Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total.	Ash	Nitric.	Ammoniacal.	Albuminoid (Wanklyn)	Organic (Kjeldahl.)	Total	In Solution.			Total.	Permt.	Tempy.
Final effluent . . .	69·30	3·30	0·80	66·0	33·0	...	...	...	...	4·15	...	9·00	...	...	...	...
Crude refuse . . .	262·60	82·70	12·00	179·9	41·7	...	0·69	4·54	9·17	31·57	14·08	...	trace	71·8	45·7	26·1
Tank effluent . . .	158·10	18·20	9·70	139·9	38·3	...	0·24	1·14	2·16	13·45	12·67	...	trace	31·9	28·7	3·2
Coal-filter effluent . .	91·90	8·40	1·35	83·5	47·0	nil	0·16	0·61	1·40	11·22	8·26	...	trace	36·0	28·7	7·3
Final effluent . . .	69·65	5·35	1·90	64·3	37·0	nil	0·07	0·26	0·66	6·75	5·63	...	trace	28·7	26·3	2·4
Crude refuse . . .	166·40	40·40	9·95	126·0	38·0	...	0·44	1·90	3·67	31·39	19·52	31·5	...	63·5	40·5	23·0
Tank effluent . . .	180·92	4·12	2·76	176·8	46·8	...	0·25	1·33	2·75	15·33	12·63	.	24·9	38·3	36·9	1·4
Coal-filter effluent . .	116·78	9·28	1·16	107·5	44·3	nil	0·05	1·14	2·25	20·28	14·30	...	13·8	45·7	36·0	9·7
Final effluent . . .	78·86	5·96	1·16	72·9	40·2	nil	0·05	0·50	0·96	11·09	8·61	...	trace	37·9	28·7	9·2
Final effluent . . .	65·28	6·08	1·00	59·2	50·7	nil	0·05	0·27	0·89	3·16	2·68	...	trace	34·1	26·3	7·8
Tank effluent . . .	129·30	11·30	2·80	118·0	36·2	nil	0·04	1·17	2·54	24·31	23·58	30·60	...	66·5	49·6	16·9
Coal-filter effluent . .	80·50	10·10	3·50	70·4	36·0	nil	0·04	0·58	1·28	9·41	7·35	5·40	.	52·2	37·1	15·1
Final effluent . . .	72·90	7·50	4·10	65·4	34·8	nil	nil	0·36	0·73	5·15	3·77	...	trace	50·7	32·8	17·9
Crude refuse . . .	91·10	33·90	13·70	57·2	28·0	nil	0·16	1·08	1·89	7·64	3·86	...	24·38	42·1	25·4	16·7
Tank effluent . . .	67·08	4·48	1·44	62·6	28·0	nil	0·02	0·33	0·76	8·34	6·12	...	24·38	42·8	20·7	22·1
Coal-filter effluent . .	59·90	10·70	4·60	49·2	28·0	nil	0·02	0·33	0·70	3·06	1·94	...	30·74	42·8	12·8	30·0
Final effluent . . .	50·88	6·48	3·52	44·4	31·0	nil	nil	0·13	0·37	1·66	1·18	...	27·56	40·7	9·4	31·3
Final effluent . . .	45·10	3·70	1·70	41·4	23·6	trace	0·01	0·19	0·35	1·92	1·36	nil	nil	25·1	16·6	8·5
Final effluent . . .	50·10	2·90	1·50	47·2	28·0	nil	0·01	0·11	0·28	1·42	1·30	...	trace	32·5	10·6	21·9

where the liquid is absorbed. Each tank is sludged on an average once in three weeks, and then contains about 3 inches of liquid sludge (say 6 cubic yards). About five loads of air-dried sludge are produced per month.

The total cost of these works, exclusive of the site, is estimated at £1050. The labour required, including the sludging, takes half a man's time, and costs 10s. 6d. a week, and about a third of a ton of lime is used weekly. Allowing 10 per cent. on the outlay for interest and depreciation, these figures give 11·6 pence per 1000 gallons as the cost of treatment.

Analyses of the refuse and effluents are given in Table XIX. The effluent is discharged into a very small stream, Shepley Dyke, the volume of which in dry weather is less than the volume of the effluent. Formerly the bed of this stream was covered with fungus (chiefly *Sphærotilus natans* with filaments of *Crenothrix polyspora*), and its water had a very offensive smell of brewery waste. Neither the smell nor the fungus has quite disappeared, but both are now little noticeable.

It will be noticed in the analyses of the final effluents that practically no nitrates are present, and this may be taken as a sign that the purification has not proceeded so far as might be wished. In the course of some experiments (*Journ. Royal San. Inst.*, 1904, vol. 25, part 3, p. 574) it was found that by finally passing a similar filter effluent through garden soil nitrates were produced, and it was because of this that the final filter at Shepley was covered with sods. Dr Calmette (*Recherches*, vol. 3, p. 74, and vol. 6, p. 208) has concluded from his experiments that in the purification of liquids such as these the carbohydrates present greatly retard, if they do not prevent, nitrification, but the experiments on the purification of barley-steeping water and of brewery refuse, which have been mentioned above, show that it is certainly possible to bring about nitrification.

Messrs Clark & Adams have gone carefully into this question, and have shown (*Journ. Ind. Eng. Chem.*, 1912, vol. 4, p. 272) that such substances as sugar, molasses, butyric acid, alcohol, and wool-scouring refuse, bodies rich in carbon, have a strong effect in checking nitrification, and may even stop it when present in sufficient proportion. They find that even when nitrification is checked the purification effected as judged by the albuminoid ammonia and oxygen-absorbed figures is not materially lessened, but that when ammonium chloride is added to the liquid under treatment this check in nitrification does not take place.

Brewery refuse, unfortunately, yields no bye-products worth recovery, so there is little prospect of the brewer's recouping himself for the expense of treatment. Much yeast is certainly allowed to run to waste which might be kept back and re-used or sold, and there is a small demand for the crude refuse by manufacturers of fine wire, who use it for wire steeping, no doubt on account of its acidity; but the quantity which can thus be disposed of is very small.

Distilling.—The Royal Commission on Sewage Disposal, 1898, have the offensive smells produced are likely to cause nuisance in the neighbourhood.

The purification of distillery refuse in contact beds has frequently been attempted, and this method was recommended by Professor Hendrick in the paper quoted above, but on the large scale the results have never been satisfactory. The reason for this has been explained in dealing with brewery refuse, and the Royal Commission conclude from their experiments that even when pot ale is diluted to ten times its original volume and treated with lime, six contacts are not sufficient to produce a good effluent.

TABLE XX.

POT ALE AND SPENT LEES.

(*Results expressed in parts per 100,000.*)

	Total Solids.	Solids in Suspension (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{8}$ permanganate at 27° C. in four hours.
		Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	
Pot ale:							
Malt distillery .	...	..	...	3·82	60·10	...	1177·8
,, ,, .	...	...	..	12·16	...	156·90	1181·0
,, ,, .	3539·0	701·5	22·5	4·90	96·00	202·70	1657·0
Grain ,, .	2666·0	1524·0	24·0	1·02	65·00	154·70	1133·6
Spent lees:							
Malt distillery .	...	...	...	0·11	0·19	0·21	53·6
,, , .	17·9	1·1	0·7	0·04	0·05	0·16	16·2
,, ,, .	24·4	3·2	1·4	0·04	0·06	0·08	17·6

The Commission found that the pot ale diluted with water to twelve times its original volume, treated with lime and settled, could be purified upon a percolating filter at the rate of 20 gallons per cubic yard per day. The filter they used was 24 feet in diameter, 12 feet deep, and was filled with coke in pieces varying from 1 inch to 3 inches in diameter. It was fed intermittently by a revolving sprinkler. The effluent from this filter was strained through a shallow filter composed of a 1-inch layer of sand lying on a 3-inch layer of gravel. The average composition of the liquor going on to the filter and of the final effluent are given in Table XXI.

The experiments of the Commission appear to show conclusively that by repeated treatment on percolating filters any necessary degree of purity in the effluent can be obtained. It will be noted in the analyses that purification had proceeded so far that nitrates were produced, corroborating the results obtained experimentally in the treatment of brewery refuse, although, as mentioned above, Professor Calmette has doubted the possibility of obtaining nitrification in liquids containing so high a proportion of carbohydrates.

The Commissioners state that the effluent was non-putrescible and absorbed oxygen only very slowly from water. Experiments were also carried out to test the effect of this effluent on a running stream, and it was concluded that the effluent would not injure any stream into which it might be discharged. It was indeed found that the effluent, even by itself, was harmless to trout.

TABLE XXI.

FILTRATION OF LIMED DISTILLERY REFUSE.

(*Results expressed in parts per 100,000*).

	Solids in Suspension.	Nitrogen.				Oxygen absorbed from $\frac{N}{8}$ permanganate at 27° C. in four hours.
		Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Nitric.	
Tank effluent . .	6·13	0·42	2·88	6·63	...	71·10
Final effluent . .	less than 1·00	0·03	0·14	0·36	0·66	1·75

Stevenson Macadam, F.I.C., F.C.S., however, in a report on these experimental works of the Royal Commission (Sixth Report, Appendix VI., p. 79), concludes that the effluents still contain objectionable polluting matter, foreign to the pure natural waters of the district. He points out that the experimental works were small in size and under highly skilled supervision, so that the results were better than would be obtained on a large working scale with ordinary attention. He suggests that the pot ale could be concentrated by evaporation and would then form a valuable cattle food, while the other waste waters could be re-used in the steam boilers and for other requirements of the distillery.

American experience supports this view, for in a report by Hermann Stabler in 1906 to the United States Geological Survey on the prevention of stream pollution by distillery refuse, a system of evaporation is fully described as in successful use at Lynchburg Distillery, Ohio, where malt, corn, and rye are distilled. Mr Stabler first discusses the nature of the waste waters, their effect upon a stream, and their purification by filtration, precipitation, fermentation, and evaporation. He comes to the conclusion that it is best to evaporate the pot ale and spent lees and to make the recovered solids into cattle food. The process adopted is to screen out all the grosser suspended matter and to dry it by filter pressing. The liquid is then evaporated in a triple-effect evaporator, and the concentrated syrup mixed with the cake from the press and dried in a hot-air drier, to be used as a cattle food. The distillate from the evaporator is used for mashing. It is shown that the process, although costly to instal, is a very profitable one, yielding, according to Mr Stabler, 73 per cent. per annum on the outlay. The adoption of this process would leave, in the case of an ordinary distillery, only the malting and washing and swilling waters to be dealt with, and this, as has been shown, is a comparatively easy problem.

Summary.—In conclusion it may be stated that the liquid refuse from all the processes of grain washing, malting, brewing, and distilling can be effectively purified by irrigation on a sufficient area of suitable grass land. For the first two kinds of refuse it may be suggested as a minimum that an acre should be provided for every 10,000 gallons of daily flow, whilst for the other two kinds at least four times this area would be necessary.

Where such land is not available the screened grain-washing refuse and the steep waters from malting can be purified by treatment upon percolating filters, followed by straining filters of sand and gravel. The rate of filtration through the percolating filters should not exceed 40 to 50 gallons per cubic yard of filtering material, and the filter effluent should not be applied to the straining filters at a rate greater than 250 gallons per square yard per day.

In the case of brewery and distillery refuse any required degree of purification can be attained by precipitation with lime, settlement in tanks, and treatment of the tank effluent by repeated applications to percolating filters, followed by sand strainers. The rate of this application to the percolating filters should not exceed 20 gallons per cube yard per day for each filtration, and the rate of application to the sand strainers should, as in the former case, never exceed 250 gallons per square yard per day. The construction and cost of such purification works are given in Chapter XI.

In the case of a distillery, the pot ale and spent lees can be profitably evaporated to dryness and used as cattle food, when the remaining waste waters can be dealt with like those from malting and grain washing.

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CHAPTER V.

THE LEATHER TRADES.

Branches of trade—Tanning—Soaks Limes—Tan pits—Mineral tannages—Leather dyeing—Currying—Fellmongering—Picker making—Rug making—Character of refuse Treatment—Bibliography.

UNDER this title may be grouped five industries, those of tanners, curriers, fellmongers, picker makers, and skin rug makers. In all five the liquid trade refuse consists in great part of animal matter in solution and suspension in water, often in a state of commencing or advanced putrefaction, is of a grossly polluting character, and is apt to give rise to great nuisance when turned into a stream.

Tanning.—The processes of tanning are rather complex and vary greatly in different tanneries, but the older and more ordinary methods may be thus briefly described. The skins, pelts, kips, or hides, as they are variously named; are first steeped and washed in pits of water—the "soaks." In the case of fresh hides this is done to wash out all dirt and blood, and soaking is then rather a misleading name for the process. The sun-dried, or arsenic or salt-cured hides from abroad, however, require to be soaked for some time until they become softened and freed from the curing material. The water in the soaks is frequently changed, usually several times in dealing with one lot of skins, or the soaks may be so arranged that a stream of water is constantly passing through them. When discharged, the water carries with it dissolved and suspended animal matters, dirt, and sand, which have been washed from the goods, and often salt or arsenic washed out from skins which have been cured with these materials.

From the soaks the skins are removed to pits containing milk of lime, and in these "limes" they are steeped for a considerable time in order to bring about a loosening of the hair. To accomplish this effectually it seems necessary that while in the limes the skins should just begin to undergo putrefaction. The process is, in fact, partly a chemical one, the lime being an active agent, and partly bacterial, the putrefaction set up by the bacteria playing perhaps the greater part in loosening the hairs from their sheaths in the skins. It is thus not necessary or indeed possible to use a fresh quantity of milk of lime for each lot of skins, for the lime pit must become ripened by the growth of bacteria before it will act properly.

The limes are therefore not often discharged, and some tanners say they never discharge them, but constantly refresh them and keep them up in strength by the addition of fresh quantities of lime and water, removing at the same time spent lime and other solids which settle at the bottom of the pits. In fact, however, the limes become clogged up with spent lime and dirt, or they become so highly charged, especially in hot weather, with putrefactive germs that they act injuriously on the skins. They are therefore from time to time discharged, although it may be at long intervals. Even if it were not so the liquids in them do escape, for they are soaked up by the skins and, when these are drawn out upon the floor of the tannery and placed upon the "beams" in order to have the hair scraped off, the lime water drains or is squeezed out of them, and is often washed down the drains when the floor is swilled. The liquid refuse from the limes is one of the worst kinds of trade refuse, being always far advanced in putrefaction, very highly charged with lime, and also with organic matter in solution; for although lime in small quantities precipitates such substances, it has a solvent effect when present in excessive amounts.

After the skins have been thoroughly scraped, first on the outside to remove all hair, and afterwards on the inside to remove loose pieces of connective tissue or "fleshings," they are treated in "bates" or "puers." These are pits of water containing, in the case of "bates," pigeon or hen dung, and, in the case of "puers," that of dogs. This mixture has the double effect of killing or neutralising the lime, which would be detrimental in the after process of tanning, and of altering the physical condition of the skins, in order to produce light leathers with a soft grain. Here again, as in the limes, the action is a complex one, partly physical or chemical, due to the organic acids present, and partly bacterial, for these acids are gradually formed by the action of living organisms on the excreta in the liquids. The contents of the bates or puers after a time become useless, partly no doubt because the liquid gets highly charged with lime from the skins, and partly because putrefactive germs develop in large numbers. The liquids are therefore discharged from time to time, and the pits made up afresh. This class of refuse, as may be imagined, is of a very objectionable character.

When removed from the bates or puers the skins are rinsed in water and are then ready for the actual process of tanning. In the ordinary process of tanning with extracts of various vegetable matters, of which oak bark may be taken as representative, the skins are placed for long periods in tan pits containing a watery extract of tanning material, being first steeped in a weak tan liquor and afterwards in liquors of gradually increasing strength. As the tanning materials are of considerable value, it is to the advantage of the tanner to prevent their escape. The tan liquors are exhausted as far as possible, and are often retained and strengthened from time to time. In such cases the tan pits are very seldom discharged and in some tanneries seem never to be let off. Generally, however, they are from time to time discharged, and in all cases there is a constant escape of small quantities of tan liquor, which drains from the skins as they are removed from one pit to another. This it is which gives the refuse of a tannery its characteristic brown colour, turning black when mixed with any iron, as for instance when the refuse is discharged into a stream the waters of which are ochrey.

The waste tan-pit liquors are not in themselves very objectionable or liable to give rise to nuisance by decomposition, but they are very detrimental to any stream into which they may be run off, as the tannin has the property of greedily absorbing oxygen, and this checks the natural process of purification which goes on in a running stream; for this purification is largely dependent upon the amount of oxygen present in the waters of the stream, the oxygen being necessary both for the life of the organisms, to the activity of which the breaking down of the organic matters in the waters is due, and also for the oxidation of the decomposition products.

In addition to the liquid refuse mentioned above there are various washing waters. For instance, the skins when taken out of the soaks are sometimes washed in pits of water or put into a revolving drum and washed with water to further cleanse and soften them, and the same cleansing process is at times adopted for the skins removed from the "limes" and "bates." From these processes considerable volumes of polluted water escape. Then again the skins are sometimes, during the process of soaking, beaten in "stocks" to soften them, and from this a small quantity of dirty water escapes. But in addition to all these direct discharges there is a large quantity of liquid allowed to drain from the skins as they are removed from one pit to another and much dirty water which comes from the swilling of the floors. All these waste waters are polluting.

Skins are also cured by dressing them with alum, oils, fats, and albuminous substances, but the liquids used in these cases are mostly valuable and are not allowed to escape, and are at any rate small in amount compared with those resulting from the common processes. In these cases too, however, dirty waters are discharged from various washing processes.

In recent years a great deal of attention has been given to the scientific investigation of the processes described above. As a result it has been found advantageous in many cases to use chemical reagents in a pure form, and thus to avoid the troubles due to the complex and putrefactive substances with which, in the older processes, they were associated. For instance, dried hides are now occasionally soaked in a weak solution of caustic soda, or formic or butyric acid. A weak solution of sulphide of sodium is sometimes used to loosen the hairs in the hides, and the waste liquid escaping from this process, although smaller in amount, is even more polluting than that from the ordinary limes. For some kinds of leather a "bran drench" is used instead of, or in addition to, the bates; this is a fermenting extract of bran in water which becomes charged with lactic and acetic acids during fermentation; or, instead of this, pure lactic or formic acid is sometimes used. In the actual tanning process the tannin is sometimes replaced or assisted by the use of bichromate of potash or soda, and as these salts are valuable the tanner takes care to discharge as little as possible.

In several of the large tanneries producing fancy leathers the skins are dyed after being tanned and the waste dyewaters are discharged along with the rest of the liquid refuse. The dyewaters, although carrying with them considerable quantities of suspended solids, are not nearly so polluting in character as the other kinds of refuse already mentioned.

At most tanneries, however, the old method of tanning still obtains, and there are thus, generally, the following kinds of liquid trade refuse:— The waste waters from the soaks, the limes, the bates or puers, and the spent liquors from the tan pits, as well as the waters dirtied in washing the skins at the various stages of the tanning processes. Each of these is highly objectionable, and all of them mixed together form a waste liquid of a most polluting character (see Table XXII.).

The volume of refuse from a tannery is always difficult to estimate. One tanner who deals with an average of 1000 hides a week discharges 30,000 gallons of trade refuse daily. Another who tans 60 hides per week uses about 3000 gallons of water per day.

J. A. S. Morrison (*Journ. Amer. Leather Chem. Assoc.*, July 1911, p. 326) estimates that a tannery having a capacity of 1500 market hides per week will probably run to waste 25,000 gallons of old tan liquors and 10,000 gallons of old limes; puers and wash waters will account for 75,000 gallons, whilst soaks add 40,000 gallons, making a weekly total of some 150,000 gallons, or say 25,000 gallons daily.

Currying.—This is a process by which tanned leather is prepared for various purposes. At many of the larger tanneries this process is also carried on, but there are numerous premises where nothing but currying is done, the leather having been tanned elsewhere. The leather as received from the tanneries is steeped in water or a watery extract of some tanning material to soften it, and is then scoured with a similar liquid in order to prepare the surface for some of the further processes. From this steeping and scouring there are discharges of the partially spent tanning extracts, and these are of a polluting character, but small in quantity and comparatively innocuous compared with the discharge from an ordinary tannery (see Table XXIII.).

Fellmongering.—The fellmonger deals with the skins of sheep and

TABLE XXII.

TANNERS' REFUSE.

(Results expressed in parts per 100,000.)

Sample of	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Hardness (as $CaCO_3$).			Alkalinity in Solution (as $CaCO_3$).
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).		Total.	Permanent.	Temporary.	
Stirred-up soak, 1st washing, foreign cured hides	309·0	10·0	1·2	299·0	265·8	7·5		1·7	6·16	66·0	46·0	20·0	...
Stirred-up soak, 2nd washing, foreign cured hides	399·0	14·0	2·8	385·0	308·2	20·4	...	3·8	14·4	60·0	53·0	7·0	
Stirred-up soak, 1st washing, dry salted hides	733·0	16·6	13·2	716·4	652·8	2·8	0·48	1·60	2·0	...		...	...
Stirred-up soak, 2nd washing, dry salted hides	201·2	8·0	4·4	193·2	171·6	1·09	0·24	0·60	1·12	...	...		...
Stirred-up soak, 1st washing, sun-dried hides	383·7	7·2	4·8	376·5	352·5	3·0	0·36	0·92	3·76	...		...	...
Stirred-up soak, 2nd washing, sun-dried hides	937·0	96·0	71·0	841·0	740·0	12·5	1·43	5·6	12·76	...	...	...	...
Stirred-up soak, fresh market hides	73·6	3·6	1·8	70·0	62·0	0·02	0·17	0·28	1·24	12·5	0·0	12·5	...
Stirred-up soak, 1st washing, fresh market hides	903·0	38·0	8·0	865·0	775·0	11·0	...	8·88	14·9	52·0	33·0	19·0	107·0
Stirred-up soak, 2nd washing, fresh market hides	218·6	27·6	6·3	191·0	168·0	4·6	1·67	2·94	6·48	22·0	14·0	8·0	35·0
¼-hour average soak, 1st washing	118·0	16·0	6·0	102·0	82·0	3·5	...	2·0	6·1	28·0	15·5	12·5	...
Liquor from lime	1216·0	313·0	173·0	903·0	510·0	18·6	...	66·0	62·5	...	...	...	320·1
Top liquor from lime	638·0	78·0	40·0	560·0	244·0	9·24	...	41·7	42·9	...	...	...	116·0
Stirred-up lime	1059·0	113·0	113·0	946·0	680·0	22·9	...	42·6	90·6	424·0	206·0	218·0	390·0
Stirred-up lime	2472·0	182·0	87·0	2290·0	915·0	31·6	...	215·6	165·3	...	...	...	526·0
Top liquor from wash after liming	706·0	86·0	66·0	620·0	362·0	16·6	...	34·5	42·7	...	...	...	273·0

Liquor from washing tumbler after liming	181·0	72·0	58·0	109·0	79·0	7·2	...	4·7	7·0	...	...	...	...
Stirred-up wash after liming	194·6	43·6	32·0	151·0	120·0	2·94	...	5·0	11·0	47·0	13·0	34·0	65·9
Stirred-up wash after liming	420·0	64·0	34·0	356·0	186·0	6·2	...	28·6	25·4	120·0	...	...	67·0
Stirred-up wash after liming	449·0	74·0	40·0	375·0	276·0	5·3	...	19·0	19·6	...	...	...	...
Stirred-up lime with sodium sulphide	5824·0	856·0	627·0	4968·0	2034·0	102·0	...	448·0	560·0	...	...	...	...
Liquor from washing tumbler after liming with lime and sodium sulphide	946·0	368·0	296·0	578·0	388·0	14·0	...	44·2	60·9	...	...	...	...
Liquor from bates	341·0	105·0	44·6	236·0	126·0	40·9		27·7	29·1	78·0	60·0	18·0	...
5 mins. average bate (pigeon and hen dung)	323·0	148·0	56·0	175·0	83·0	28·7	...	9·8	34·3	72·0	39·0	33·0	...
Stirred-up puer (dog dung)	362·0	170·0	75·0	192·0	108·0	15·4		9·4	25·8		...	...	...
Stirred-up puer (dog dung)	376·0	204·0	83·0	172·0	109·0	13·3		10·8	25·8		...	...	...
Stirred-up bate (pigeon dung)	222·5	34·5	26·4	188·0	106·0	23·7	...	6·9	21·7	14·0	14·0	...	...
Stirred-up bate (pigeon dung)	768·0	68·0	29·0	700·0	291·0	10·8		65·7	56·2	...			110·0
Stirred-up bate (pigeon dung)	329·0	56·0	12·0	273·0	161·0	33·8		7·3	23·3		...	...	...
¾-hour average washing after bate (pigeon dung)	76·0	15·0	2·0	61·0	49·0	4·76	...	1·57	3·40	23·0	10·5	12·5	...
Bran drench	401·0	63·0	5·0	338·0	153·0	2·1		23·6	24·3	...	...	...	...
Liquor from tan pit	202·0	27·0	2·6	175·0	88·0	0·14	...	1·86	75·6	44·0	30·0	14·0	...
Stirred-up spent tan liquor	3032·0	2142·0	34·0	890·0	846·0	0·26	...	16·2	808·0	593·0	593·0	...	...
Liquor from graining tumblers	2760·0	185·0	15·0	2575·0	661·0	2·6	...	12·5	949·6	440·0	...		...
¼-hour average leather steeping before splitting	82·0	33·0	13·0	49·0	25·0	0·03	...	1·40	19·3	10·5	6·0	4·5	...
Hour average mixed refuse	1520·0	532·0	298·0	988·0	554·0	15·9	...	30·4	242·5	562·0	376·0	186·0	300·0
Hour average mixed refuse	665·0	110·0	39·0	555·0	494·0	13·0	...	7·44	34·6	42·0	15·0	27·0	97·0
Hour average mixed refuse	345·0	131·0	18·6	214·0	124·0	7·0	...	10·5	55·8	59·0	46·0	13·0	...
½-hour average mixed refuse	419·0	101·0	54·0	318·0	298·0	2·4	...	5·2	12·1	184·0	124·0	60·0	95·0

lambs, and as a rule prepares the skins by removing the wool from them and sells them to a tanner to be further dealt with. The processes adopted are like those in the first stage of tanning. The skins are washed in soaks to remove dirt and blood, steeped in milk of lime to loosen the wool, and scraped or stripped clear of wool and fleshings. They are then either steeped in lime water or pickled with sulphuric acid and salt and sent off to the tanner. Sometimes the first washing of the skins is done in a "burring" machine, in which the skins are passed through rollers to cleanse them of dirt and vegetable seeds, which are washed away in a constant stream of water. Sometimes the loosening of the wool is brought about by a putrefactive process without the aid of lime, the skins being hung up in a warm damp atmosphere until putrefaction has so far advanced as to loosen the wool sufficiently for it to be pulled off by hand. In other cases the skins are covered on the inside with a lime paste and stacked wool to wool, instead of being placed in a lime pit containing milk of lime.

Table XXIII.

CURRIERS' REFUSE.

(*Results expressed in parts per 100,000.*)

Sample of	Total Solids	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.)		Nitrogen.		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Hardness (as $CaCO_3$).		
		Total	Ash	Total.	Ash.	Ammoniacal	Organic (Kjeldahl).		Total	Permt.	Ten
tirred-up steeping liquor (sumac)	5456·0	988·0	86·0	4468·0	592·0	0·9	28·8	3184·0		..	.
our average scour	1084·0	492·0	14·0	592·0	208·0	0·01	11·7	753·0	132·0	92·0	4
our average scour	2156·0	1772·0	106·0	584·0	158·0	1·31	44·0	1215·0	250·0	120·0	13
our average scour .	1858·0	880·0	358·0	978·0	218·0	0·99	17·2	774·0	195·0	132·0	6
cour liquor . .	452·0	296·0	5·0	156·0	50·0	0·06	6·94	301·0	50·0	28·0	2

The ordinary discharges from a fellmonger's yard are thus, first, the water which has been used for soaking or washing the skins, and this is often large in amount, because a constant stream of water is passed through the soak in many cases; secondly, the spent liquids discharged at intervals from the lime pits; and, thirdly, the washing waters through which the skins have passed after being removed from the lime pits and after being stripped of wool.

The mixed refuse from a fellmongery is very similar to that from the limes in a tannery, although perhaps not so concentrated. It is highly charged with lime and organic matter both in solution and suspension (see Table XXIV.).

TABLE XXIV.

FELLMONGERS' REFUSE.

(Results expressed in parts per 100,000.)

Sample of	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Hardness as $CaCO_3$.			Alkalinity in Solution (as $CaCO_3$).
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Organic (Kjeldahl).		Total.	Perm.	Tempy.	
Hour average soak	378·0	114 0	65·6	264·0	180·4	2·88	12·3	22·2	120·0	92 0	28·0	76·0
Stirred-up soak, 1st washing	111·0	36·0	18·0	75·0	47·0	3·0	2·04	6·52	16·5	6·0	10·5	...
Stirred-up soak, 2nd washing	95·0	12·0	4·4	83·0	41·0	7·27	3·23	8 88	18·0	4·0	14·0	...
Water from burring machine	242·0	202·0	116·0	40·0	24·0	1·55	4·75	7·90	19·5	6·5	13·0	...
Hour average soak	202·0	70·0	36·0	132·0	98 0	4·0	3·28	9·32	34·0	9·5	24·5	62·0
Hour average lime	181·0	34·0	17 6	147·0	115·0	4·27	3·32	4·9	47·0	26·5	20 5	42·0
Hour average lime	1182·0	268·0	151·6	914·0	434·0	13·6	69·2	63·6	...	...	...	...
Liquor from lime pit	2522·0	394·0	208·0	2128·0	936·0	44·3	175·4	145·7	...	...	...	...
Liquor from lime pit	497·0	47·0	27·6	450·0	310·0	4·1	23·9	22·5	230·0			95·2
Stirred-up lime (paddle)	1758·0	956·0	542·0	802·0	382·0	46·5	96·0	95·3	...	...	...	...
Hour average washing after liming	327·0	27·0	12·0	300·0	281·0	10·27	2·58	4·3	77·5	55 0	22·5	109·0
½-hour average washing after liming	123·2	15·2	9·0	108·0	95·0	1·64	1·02	1·26	15·0	6 0	9·0	22·7
Stirred-up washing after liming (paddle)	232·0	154·0	30·0	78·0	36·0	32·3	13·3	26·6	42·0	15·0	27·0	...
Hour average washing after liming	194·0	41·0	25·6	153·0	128·0	1·7	1·5	4·48	76·0	48·0	28·0	65 0
Hour average mixed refuse	866·0	176·0	106·0	690·0	444·0	14·0	42·0	39·5	...	...	...	195·0
Hour average mixed refuse	1056·0	648·0	446·0	408·0	328·0	9·7	18·6	41·6	...	...	...	...
Hour average mixed refuse	224·0	174·0	117·0	50·0	33·0	4·6	4·36	12·6	30·0	9·5	20·5	...
Hour average mixed refuse	390·0	191·0	117·0	199·0	175·0	1·23	3·53	10·4	69·0	45·0	24·0	12·5

Fellmongers, in comparison with tanners, do not require to use a great quantity of water. At one place where ninety skins a day are dealt with, the water used amounts to 1800 gallons daily. In another case, where the water is supplied by meter, 3000 gallons are used for every hundred skins. Where a burring machine is used the volume of refuse may be much greater, as from that alone 1500 gallons may be discharged for every hundred skins.

Picker Making.—A picker maker cures skins for a special purpose. The picker is that portion of a loom which drives the shuttle from side to side, and as it must come constantly and forcibly into contact with the pointed end of the shuttle, it must be made of elastic yet durable material. The material used is the very thick hide of the East Indian buffalo cured in a particular way. The hides are generally received in a sun-dried state and are soaked first in water pits to soften them, then in lime pits, unhaired, and finally cleansed free of lime in wash pits.

Here again the mixed liquid refuse (see Table XXV.) is highly charged with animal matter and with lime, and is similar in character and amount to that of the fellmonger. At many picker works, however, the hides are received ready cured, and the only wet process they go through is steeping in water to soften them and to make them easy to manipulate and to cut up. In such cases there is frequently a stream of water running constantly through the steeping tanks, and the discharge of this water into a stream causes very little pollution.

Rug Making.—There is another group of manufacturers who cure skins to be made into rugs. The skins are cured by a dry process, but are generally washed with soap and water and frequently are dyed. To finish their preparation they are placed in running water, the action of which is said to help greatly in producing a good appearance in the rugs. The waters used for cleansing the skins and the waste dyewaters form a polluting discharge, which is usually, however, only small in amount.

Character of Refuse and Treatment.—The waste waters from the various branches of the leather trade are mostly of a very polluting character. They are highly charged with suspended matters and dissolved solids, both organic and inorganic. They nearly always swarm with putrefactive organisms, and were it not for the quantity of lime present would be unbearably offensive. The process of putrefaction is checked by the presence of the lime, but when the refuse is diluted by being discharged into a stream the effect of the lime is weakened and putrefaction sets in rapidly.

Analyses of the various kinds of refuse are given in Tables XXII. to XXV. For comparison analyses are also given in Table XXV. of two typical domestic sewages, and it will be noted that in every case the mixed trade refuse is a much more polluting liquid than an ordinary domestic sewage.

The complete purification of liquids so complex and so highly charged

TABLE XXV.

PICKER MAKERS' REFUSE.

(*Results expressed in parts per 100,000.*)

Sample of	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Hardness (as $CaCO_3$).			Alkalinity in Solution (as $CaCO_3$).
		Total.	Ash.	Total.	Ash	Ammoniacal.	Organic (Kjeldahl).		Total.	Permt.	Tempy.	
Stirred-up soak	178·0	63·0	30·0	115·0	74·0	18·7	5·1	11·8	...	...	...	...
Stirred-up soak	316·0	67·0	40·0	249·0	143·0	7·5	13·4	17·6	84·0	76·0	8·0	...
Top liquor from soak	97·0	17·0	3·7	80·0	68·0	13·7	5·6	2·8	.	...	...	80·0
Stirred-up soak	228·0	40·0	27·0	188·0	108·0	3·5	11·8	11·6	60·0	48·0	12·0	...
Stirred-up lime	3462·0	1468·0	1178·0	1994·0	816·0	47·0	279·7	183·0	...	...	...	...
Top liquor from lime	2630·0	1050·0	...	1580·0	..	61·6	119·8	109·0	...	...	...	500·0
Stirred-up wash after liming	230·0	89·0	52·0	141·0	99·0	4·5	9·0	9·7	...	..	...	..
Wash liquor after liming	441·0	23·0	15·0	418·0	262·0	11·0	28·3	23·7	...	...	...	...
Stirred-up wash after unhairing	746·0	432·0	403·0	314·0	221·0	15·7	20·4	25·4	...	...	..	.
Wash liquor after unhairing	149·0	40·0	25·0	109·0	76·0	4·4	7·5	7·1	..	...	...	...

DOMESTIC SEWAGE.

Sample of	Total Solids.	Solids in Suspension: Total.	Solids in Suspension: Ash.	Solids in Solution: Total.	Solids in Solution: Ash	Nitrogen: Ammoniacal.	Nitrogen: Organic (Kjeldahl).	Oxygen absorbed	Hardness: Total.	Hardness: Permt.	Hardness: Tempy.	Alkalinity
Average sewage of a privy-midden town	162·32	70·61	17·93	41·71	61·49	6·70	3·39	11·40	32·6	11·3	21·3	...
Average sewage of a water-closet town	82·96	31·98	6·89	50·98	41·71	4·89	2·34	5·67	18·6	11·4	7·2	...

with organic matters is not an easy matter. It is fortunate that in most cases Sanitary Authorities are willing to receive the refuse into the public sewers for treatment along with the domestic sewage, and this is generally the best course to be adopted.

Where a manufacturer in the leather trade is obliged to deal with his own trade refuse he must nearly always treat it first for the settlement of the suspended solids, and for this purpose it should be passed through effective settling tanks (see Chapter XI.). In the case of tanyard refuse the lime liquors and the tan liquors precipitate one another to some extent, but it will be found advantageous to use additional precipitants, such as lime and copperas used together, or alumino-ferric. In using such *precipitants care must be taken to have sufficient lime present, or the iron* may combine with the tannin to form an inky solution.

The tank effluent after precipitation is still a very impure liquid, more polluting than any ordinary domestic sewage, but is in such a condition that it can readily be further purified. Where a sufficient area of suitable land is available this purification can be best effected by careful irrigation, and at many of the smaller tanneries this method is adopted with success. The area required for irrigation is considerable even where the soil is suitable, and probably at least an acre should be allowed for every 5000 gallons of the daily flow. Where suitable land is not available the tank effluent can be purified to any desired extent by one or more applications to percolating filters (see Chapter XI.), followed by straining through a sand filter to remove the humus or residual suspended matter. This is evident from the results obtained by the Massachusetts State Board of Health (Forty-first Annual Report, 1909, p. 349). The percolating filter used by them was composed of broken stone to a depth of 6 feet, and was supplied with the liquid at rates varying from 100 to 300 gallons per square yard per day; but these rates appear to be rather excessive in dealing with such a liquid. For ordinary tanyard refuse, precipitated and settled, probably 50 gallons per square yard per day on a 6-foot filter would be as high a permanent rate as would be advisable (cp. Royal Commission on Sewage Disposal, 1898, Fifth Report, pp. 117–118). In these Massachusetts experiments, further details of which are given in the Forty-second Annual Report, 1910, p. 266, the filter effluent was strained through a sand filter at rates varying from 15 to 30 gallons per square yard per day, and "the effluent from this filter was well nitrified, stable, and practically odourless." If, as suggested above, the refuse were passed through the percolating filter at a lower rate, and especially if a humus tank were interposed, then no doubt a much larger volume per square yard could be passed through the sand strainers, say 250 gallons, an amount which would be allowed by the Local Government Board in the case of domestic sewage.

Professor Dunbar of Hamburg has demonstrated by experiment that refuse of this kind can be rendered non-putrescible by treatment in double contact beds; but it is evident from the nature of the liquids, and especially from their greedy absorption of oxygen, that the contact beds are not so suitable as percolating filters. This is also borne out by experience at sewage works where a large proportion of tannery refuse is mixed with the sewage.

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CHAPTER VI.

THE PAPER TRADE.

Raw materials—Processes for different kinds of paper—The paper machine—Volume of waste water—Treatment—Causticising—Separate treatment of kier liquors—Re-use of recovered fibre—Analyses—Wood-pulp manufacture—Bibliography.

THE nature of the liquid refuse from paper making depends chiefly upon the kind of raw materials used; and as these include such widely different substances as rags of linen and cotton, rough sacking, old ropes, old paper, esparto grass, straw, and wood pulp, it can readily be understood that the refuse from different mills may be very dissimilar. In addition to the refuse produced from the raw materials, there are discharges of the various substances used in the processes of manufacture, such, for instance, as the lime and soda used for the cleansing and disintegration of the fibrous materials employed, and the bleaching, colouring, sizing, and filling reagents; so that the resulting combined refuse has a very complex character. To give a proper idea of the various kinds of refuse, it will, perhaps, be simplest to describe the processes of paper making as carried on in particular mills where different kinds of paper are made.

In one mill where a high-class notepaper is made and the raw materials are chiefly linen and cotton rags, mostly the latter, with the addition of some wood pulp, the rags, after being sorted, are cut into small pieces, and passed through a "willeying" machine, for the purpose of cleansing them of dust. They are then boiled, under slight steam pressure, with water and caustic soda, of which from 5 to 10 per cent. of the weight of the materials is used. After the caustic liquid is run off, they receive, while still in the boiler, one rinsing with water, and are passed into the "washer," where they are thoroughly washed with a large quantity of clean water. They pass out of the washer through rollers which express most of the water, and are conveyed to the "breaker," where, along with the wood pulp, they are torn up into their constituent fibres, and receive a further washing. Through both the washer and the breaker a current of water is constantly passing, so that what is first discharged is considerably fouled, but the processes are continued until the escaping water is clean.

The next process is that of bleaching, where the materials, now in the condition of "half pulp," are treated with dilute chlorine liquor, "soured" with sulphuric acid, and rinsed in clean water. From the bleaching process, after being again pressed nearly dry, the half pulp is conveyed to a "beating engine," similar in construction to the "breaker," in which are added colouring and "loading" materials, and from which the liquid pulp passes to the paper machine.

The paper machine is very complicated, but consists essentially of an endless band of wire cloth kept moving forward horizontally. The pulp as it falls on to the wire cloth is spread evenly upon it, the fibres are felted by a lateral jerking, and finally a continuous sheet of paper is formed, the water escaping through the meshes of the cloth. The wire cloth delivers the wet sheet of paper on to a continuous roll of felt, which carries it forward to deliver it again to a series of rollers and heated cylinders, from which it issues as the finished article.

All the water which has been strained from the pulp, carrying with it a large amount of fine fibres along with loading and colouring materials, escapes into a tank under the machine, and from this most of it is pumped back to be mixed again with the pulp. There is always, however, an excess of this "backwater" which has to be dealt with as refuse.

From the above it will be gathered that the sources of pollution in the process of paper making at this mill are somewhat as follows, and under the same heads the discharges from all paper mills can be classed. The quantities of refuse given are only approximately correct, and it must be premised that at this mill only high-class papers are made, and the supply of water is practically unlimited, so that probably more water is used than at most mills.

	Gallons Per Ton of Paper.
(1) The waste alkali used for the boiling, termed technically the "boilings"	4,000
(2) The water in which the rags are rinsed after boiling, known as the "coolings"	
(3) The water from the washer	12,500
(4) The discharge from the breaker	50,000
(5) The spent chlorine and acid waters from the process of bleaching	2,000
(6) Any excess of the water which has passed through the wire cloth of the paper machine	15,000
(7) As a paper mill must be kept scrupulously clean, a large amount of water is used for swilling the floors	4,500
(8) In the making of the bleaching solution there results a limey sludge, which should, however, not be allowed to escape along with the liquid waste.	
Total	88,000

In another mill, where white printing paper is made from wood pulp, the pulp is thoroughly washed in a washer, is bleached in the same machine with chlorine liquor and weak acid, and again washed. It is then put into the beater, where the necessary loading is added, and from the beater the pulp is delivered to the paper machine. The excess of water from the machine is passed through a "stuff catcher," in which most of the fibrous matter is retained, while the water overflows and is partly pumped back into the washer, and partly allowed to escape. The polluting liquids are thus the discharges from the washer and some of the water escaping from the machine.

At a third mill "press paper" is made. This is a stiff brown cardboard, highly polished, which is used in the cloth trade to be placed between the layers of cloth during pressing. Heat is applied to the cloth during the process, and thus the paper must be of such a nature as not to injure the cloth even when heated.

The raw materials from which press paper is made are hemp and jute, usually in the form of sacking or old ropes. These are cut up by hand into pieces of convenient size and passed through a rag-grinding machine, where they are torn into small fragments. They are then boiled with milk of lime under steam pressure, partly for cleansing purposes and partly to disintegrate the material into its component fibres. To a ton of raw material about 2 cwts. of lime and 500 gallons of water are added. The material after this boiling is taken to the rag engine, where it is first washed and then beaten in water to form the pulp for the paper machine. In the paper machine in this case the pulp is delivered on to an endless "blanket" or roll of flannel, through which the water escapes and leaves the pulp to form the sheet of paper.

The refuse waters are therefore the lime liquid from the boilers, the dirty water from the rag engines, and the excess of water from the paper machine. Much of this waste water from the paper machine comes from the process of cleansing the blanket on to which the pulp is discharged. The blanket is in the form of an endless belt, carrying the pulp forward to a roller from which the paper is taken off by hand. As the blanket returns under the machine to the point where it receives the pulp it is cleansed of adhering fibres by a series of jets of water which play on it constantly. Owing to the filtration of the waste water through the flannel and its dilution by this large amount of cleansing water, the waste from the machine in this case contains much less impurity than in other classes of paper works. It is in fact in this case simply passed through a "save-all" to recover fibre, and then discharged without further treatment and with little detriment to the stream

At many mills esparto grass is used as a raw material. This is boiled under steam pressure in a solution of caustic soda, which dissolves out silica, resin, and various other organic matters, amounting to 50 per cent. of the weight of the grass. The weight of soda used is about 10 per cent.

of that of the raw material. When the first "boilings" have been drained off, clean water is run into the boilers and steam is again turned on. The resulting liquid is also drained off, and further quantities of cold water are added, partly for cooling and partly for washing the grass. The boilings and the first washings are both grossly polluting liquids, the former sometimes containing over 8000 parts of solid matter per 100,000, and the latter about a quarter of this amount. The later washings are less polluting in character, but are still quite unfit to discharge to a stream. The boiled grass is then transferred to the washers and treated in the same manner as rags, and the polluting discharges from further processes are similar to those already described as produced in the manufacture of paper from rags.

The quantities of the various polluting discharges from a paper mill have already been given in the description of the processes, and the total amounted to 88,000 gallons per ton of paper in the case of a mill where a high-class notepaper is made. The Royal Commission of 1865 (First Report, p. 19) found the quantity of water used per ton of paper to be nearly 250,000 gallons, while Arnot in his Cantor Lectures of 1877 estimated it to be between 30,000 and 40,000 gallons. In the evidence given before the Royal Commission of 1898 (Seventh Report, vol. 3, Q. 30.376) it was stated that

> "in rag mills, for every ton of paper made the effluent may be as high as 150,000 gallons. In an esparto mill where water is very scarce—they use esparto, and a certain amount of prepared wood—the effluent is 10,000. In another mill, using rags, esparto, and some wood, but bleaching everything, it is about 30,000 gallons per ton of paper."

The difference in these estimates is, no doubt, partly due to differences in the raw material used, and to the quantity of water available, but probably is also partly due to the re-use of much of the water in modern methods of paper making.

The refuse from paper mills generally contains in suspension large quantities of fibres and mineral matter, such as china clay and sulphates of barium and calcium, and in solution much organic matter dissolved out of the raw materials and arising from the animal and vegetable matters used in sizing, as well as colouring matter and salts of lime. There is also frequently free chlorine present, which has been allowed to escape from the bleaching process, but this is quite unnecessary, and can be prevented by careful management. Such refuse discharged into a stream may give rise to great nuisance. The solids in suspension are deposited in the bed of the stream, and as many of the solids in solution are only kept dissolved by the alkali present, they also are deposited when the alkalinity is reduced by dilution. The sludge thus deposited soon ferments and decomposes, giving off sulphuretted hydrogen and other offensive gases.

The treatment of the refuse is comparatively simple in principle. The most polluting liquids and the most difficult to purify are the alkaline "boilings," first washings, and "coolings," and where soda is used in the boilers, as in the case of mills where esparto grass is the raw material, it is found best to evaporate these liquids to dryness, and to incinerate the dried residue for the recovery of the alkali as carbonate of soda (see pp. 275 and 282). This is a profitable proceeding, for as much as 75 per cent. of the soda can be recovered and used over again (see Royal Commission, 1898, Seventh Report, vol. 3, Q. 29,825). The caustic soda used in the boilers is usually obtained in the first instance from soda ash by "causticising" with lime, and the incinerated residue from the evaporating process is treated in the same manner.

In this causticising process the carbonate of soda is dissolved in water by the aid of steam, and to the solution thus formed, milk of lime is added in sufficient quantity to combine with the carbonic acid and set the soda free. The caustic solution thus obtained is used in the kiers or rag boilers; the carbonate of lime is deposited as sludge, and, like the similar deposit in the preparation of the bleaching solution, should never be discharged with the liquid refuse, but should be removed with the rest of the solid refuse of the mill. This sludge is large in amount and may be costly to dispose of, but has some value for agricultural purposes (Hendrick, *Chemical Trade Journal*, 1912, 21st September, p. 295). It has been suggested that its production (see Hubner, *Cantor Lectures on Paper Making, Society of Arts*, 1903, p. 17, and Royal Commission on Sewage Disposal, 1898, Seventh Report, vol. 3, Q. 29,777) can be avoided by using the causticising process of Brunner, Mond & Co., in which the soda ash at a high temperature is treated with ferric oxide, which expels the carbon dioxide and combines loosely with the soda. The compound thus formed readily decomposes on addition of water into caustic soda and insoluble ferric oxide, and the latter can be re-used.

In mills where the raw materials are boiled with lime, the alkaline waters should be discharged into a cooling and storage tank, from which they should be gradually let off to mix in a somewhat uniform manner with the rest of the refuse.

The mixed refuse should then be passed through effective settling tanks (see Chapter XI.), and alumino-ferric will be found to assist the clarification. If the settling tanks are sufficiently large and well arranged and the effluent is to be discharged into a stream of sufficient size, no further purification may be necessary; in other cases some form of filtration may be required.

In Fig. 10 a plan is given of the purification works at the first mill mentioned (p. 84). These consist of a storage tank for the reception of the refuse from the rag boiler, so that it can be discharged gradually to mix with the rest of the refuse, three settling tanks, followed by a patent filter, and a sludge press fed by an elevator. The filter in this case (Wilson's patent, made by Masson, Scott & Co., Ltd., New Wandsworth) is in duplicate, each half consisting of a rectangular cast-iron cistern filled with sand as filtering medium. Above the level of the filter a flushing cistern is fixed, which is kept constantly supplied with clear or filtered water. When the tank effluent is passed through the filter the sand soon becomes clogged by the solids retained on the surface, and when this happens the liquid ponds on the surface until it reaches a height which sets a syphon in action, with the result that the effluent from the filter is automatically stopped while the flushing water from the elevated cistern is admitted underneath the filtering medium, together with a supply of air. This current of air and water passing upwards through the sand washes out the deposited solids, which are discharged again to the settling tanks. This washing comes automatically to an end and the filter again comes into action.

The capital outlay on the whole plant, as shown in the illustration, including land for tipping the sludge, was £1500. The annual charges are given approximately at £150, including £18 for depreciation, £40 for wages, £17 for steam, and £75 for interest on capital.

Fig. 11 shows the purification works at the second mill (p. 86). They consist of two large settling tanks to which the refuse is pumped, a filter of ashes upon broken stone, and a sludge lagoon.

Many other plans of purification works can be found in the Fourth Report of the Royal Commission, 1868 (p. 62), in Mr Naylor's book on *Trades' Waste* (p. 216), and in a Report on Trade Refuse by Dr Schiele (*Mitteilungen aus der Königlichen Prüfungsanstalt zu Berlin*, vol. 11).

Table XXVI. shows the composition of the various kinds of refuse and the results of treatment. From this treatment of the refuse large quantities of sludge result, consisting in great part of fibrous matter which can be used for making inferior kinds of paper.

At the first of the two mills mentioned above 100 tons of sludge per annum are obtained from a daily flow of 330,000 gallons of refuse, and the manufacturer has been so struck by this waste of material that he is at present introducing apparatus for the recovery of much of the fibrous material from the waste waters. At the second mill about 45 tons of paper are made weekly, and the sludge recovered from the purification works amounts to 50 tons per annum, but in this case only wood pulp is used as the raw material, and great care is taken to prevent escape of fibre.

The sludge thus recovered from the combined refuse is, however, mixed with all the dirt which has been washed out of the raw material, and the fibrous matter is unusable. The better plan is to treat the waste discharged from the breakers, the beaters, and the paper machine separately for the recovery of pulp, which is then fit for use as a raw material, leaving the dirty water from the boiler and washer to be otherwise dealt with.

At Darwen Paper Mill, Lancashire, where wood pulp is the chief raw material used, a very excellent set of settling tanks has been provided for the purification of waste waters. The larger proportion of these tanks is set aside for dealing with the cleaner waters, and the sludge deposited in them is pressed and used over again in the mill. By this arrangement

TABLE XXVI.

PAPER TRADE REFUSE.

(Results expressed in parts per 100,000.)

Nature of Liquid.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Nitrogen.			Hardness (in terms of $CaCo_3$).			Alkalinity (as Na_2CO_3).
		Total.	Ash.	Total.	Ash.		Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Total.	Permanent.	Temporary.	
Where rags and wood pulp are made into notepaper.													
Boilings and coolings combined	739·00	15·00	2·00	724·0	316·0	82·50	3·08	5·14	12·67	4·6	3·9	0·7	202·4
Rag washings	113·00	88·00	44·00	25·0	15·0	8·32	nil	0·25	1·76	14·1	5·3	8·8	10·0
Effluent from "breaker"	41·10	27·60	9·44	13·5	10·5	1·24	0·02	0·05	0·18	8·1	6·7	1·4	nil
Overflow from paper machine	107·00	50·00	24·00	57·0	45·0	3·26	0·04	0·12	0·25	22·9	19·6	3·3	nil
Combined refuse	89·70	40·70	18·20	49·0	35·0	4·64	0·06	0·22	0·69	14·1	10·7	3·4	nil
Effluent from settling tanks	56·24	8·24	4·80	48·0	36·0	2·28	0·05	0·15	0·47	15·6	14·8	0·8	trace
Effluent to stream from Wilson filter	48·76	3·76	2·24	45·0	37·0	0·89	0·01	0·05	0·22	17·2	16·4	0·8	nil
Stream water above mill (used in mill)	10·00	very	small	10·0	8·0	0·14	0·010	0·009	0·023	3·9	3·2	0·7	nil
Stream water below mill	9·00	very	small	9·0	7·0	0·13	0·010	0·009	0·023	3·9	3·5	0·4	nil
Effluent to stream from Wilson filter	30·00	4·00	1·32	26·0	17·0	1·06	0·03	0·05	0·18	9·6	8·9	0·7	trace
Stream water above mill (used in mill)	10·00	very	small	10·0	6·0	0·10	trace	trace	0·054	5·0	4·6	0·4	nil
Stream water below mill	20·40	2·40	1·24	18·0	10·0	0·56	trace	0·060	0·233	7·1	6·7	0·4	trace
Where wood pulp is made into white printing paper.													
Water used	9·00	very	small	9·0	6·0	0·04	0·005	0·004	0·020	4·6	4·6	nil	nil
Refuse from washing of wood pulp	871·80	42·80	12·00	829·0	622·0	20·00	0·02	0·05	0·24	665·5	665·5	nil	trace
Refuse from paper machine	583·40	385·40	275·80	198·0	164·0	7·12	0·02	trace	0·08	124·8	118·4	6·4	*4·4
Refuse from paper machine (from Füllner's stuff catcher)	131·60	7·60	6·00	124·0	107·0	0·66	0·036	nil	nil	86·1	82·1	4·0	*4·9
Mixed refuse before treatment	404·60	29·60	11·60	375·0	266·0	8·60	trace	trace	0·08	251·2	236·0	15·2	trace

Effluent from settling tank . .	248·08	10·08	5·36	238·0	179·0	4·34	trace	trace	0·14	133·1	133·1	nil	trace
†Final effluent entering stream .	228·04	7·04	3·20	221·0	176·0	4·12	trace	0·03	0·12	148·4	148·4	nil	trace
Mixed refuse before treatment .	105·04	15·44	10·08	89·6	67·0	1·82	nil	0·02	0·05	50·2	50·2	nil	nil
Effluent from settling tank . .	156·24	4·24	2·92	152·0	121·0	2·32	trace	trace	0·09	90·1	82·1	8·0	nil
†Final effluent entering stream .	156·93	4·96	2·92	152·0	122·0	2·38	nil	trace	0·08	90·2	90·2	nil	nil
Final effluent entering stream .	76·60	2·20	1·70	74·4	60·8	0·83	. .	...	...	41·1	40·5	0·6	...
Final effluent entering stream .	103·10	1·70	1·20	101·4	71·8	1·32	...	...	...	53·7	47·8	5·9	...
Where hemp and jute are made into press paper.													
Water used	27·60	3·60	2·80	24·0	16·0	0·44	0·03	0·03	0·12	14·8	9·6	5·2	nil
Discharge from boiler . . .	2746·80	10·80	6·00	2736·0	1259·0	287·00	19·12	16·21	30·86	1256·0	1256·0	nil	593·6
Discharge from rag engine . .	328·00	182·00	103·00	146·0	111·0	24·70	0·06	0·83	1·82	392·0	392·0	nil	190·8
Refuse from paper machine . .	40·40	8·40	3·60	32·0	21·0	2·42	trace	0·05	0·14	16·4	14·8	1·6	trace
Final effluent after treatment .	338·96	5·36	3·76	333·6	168·6	26·04	0·97	1·80	2·62	212·9	200·9	12·0	129·8
Final effluent after treatment .	384·00	2·00	1·88	382·0	215·0	28·80	0·92	1·72	4·02	228·6	228·6	nil	156·8
Where rags, hemp, and jute are made into printing and cartridge paper.													
Water used	50·00	very	small	50·0	41·0	0·16	0·01	0·01	0·03	17·2	13·3	3·9	trace
Refuse from washing of rags .	1287·00	836·00	454·00	451·0	282·0	107·00	1·00	9·30	19·80	590·0	296·8	293·2	561·8
Refuse from washing of jute .	92·60	32·60	15·00	60·0	42·0	7·12	trace	0·07	0·37	22·8	14·8	8·0	27·5
Refuse from washing of rope .	1392·00	922·00	410·00	470·0	268·0	177·00	0 50	5·90	11·40	665·5	264·5	401·0	179·6
Refuse from washing of hemp, jute, and canvas . . .	472·00	231·00	97·40	241·0	177·0	45·00	0·25	1·12	2·76	251·2	133·1	118·1	216·2
Refuse from washing after bleaching rags	295·00	55·00	16·00	240·0	190·0	3·36	0·05	0·04	0·22	148·4	148·4	nil	nil
Refuse from paper machine . .	158·00	38·00	17·00	120·0	94·0	5·10	0·02	0·24	0·27	45·7	42·4	3·3	*trace
Mixed refuse before treatment .	202·00	131·00	58·00	71·0	56·4	8·98	0·03	0·04	0·08	26·6	20·4	6·2	nil
Effluent from pulp recovery plant	74·64	4·64	2·40	70·0	55·0	1·54	0·05	0·01	0·03	22·1	18·0	4·1	nil
Final effluent to stream . .	79·60	1·60	1·20	78·0	63·0	1·10	0·07	0·11	0·14	31·3	21·2	10·1	trace
Where wood pulp is made into news and cartridge paper.													
Water used	51·0	very	small	51·0	37·0	0·12	0·046	trace	nil	28·1	17·2	10·9	trace
Refuse from paper machine . .	228·2	181·2	104·0	47·0	33·0	8·56	0·050	0·020	0·110	228·5	195·0	33·5	trace
Overflow from paper machine .	151·0	68·0	34·0	83·0	66·0	6·48	0·040	0·030	0·040	31·3	26·6	4·7	*trace
Refuse from pulp press . .	110·0	very	small	110·0	81·4	1·46	0·030	0·016	0·029	50·1	29·7	20·4	trace
Overflow from stuff catcher . .	109·4	6·4	5·2	103·0	79·0	2·08	0·050	trace	0·110	44·0	32·9	11·1	nil
Final effluent to stream (tidal) .	112·0	16·0	4·0	96·0	80·0	2·90	0·010	0·020	0·100	40·8	26·6	14·2	trace

* Acidity as H_2SO_4.

† The filter in this case was not in good order.

more than half the total sludge can be re-used, thus avoiding great waste and lessening the amount of sludge for which a tip has to be found.

It is increasingly the practice to attach a fibre-saving machine, such as Füllner's Stuff Catcher (Fig. 12), to each paper machine. To this, any overflow from the "stuff chest" which feeds the paper machine and all the water draining from the latter are discharged. From these liquids the fibrous matter settles and is returned continuously into the stuff chest. One great advantage of this process is that it is continuous and that the recovered fibre can be used up again immediately, no pressing or storing being required. Several manufacturers state that the pulp saved by such means yields a handsome profit, increasing the output of paper by 2 or 3 per cent. The removal of so much solid matter from the refuse, moreover, greatly lessens the amount of sludge to be dealt with, and renders the treatment of the rest of the refuse much easier.

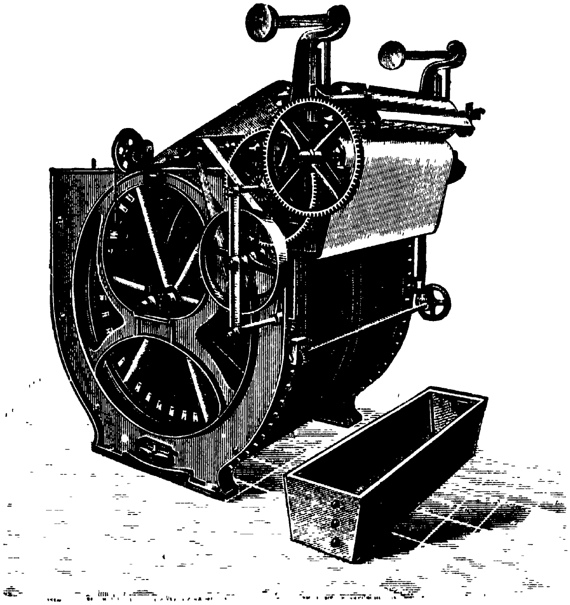

FIG. 13.—Fullner's Filter. (Otto Lechla, London.)

There are other forms of fibre-saving apparatus, such as the patent tanks of Mr M. Allen, C.E., of Manchester, Fullner's Filter (Fig. 13) and a conical "Save All" (Fig. 14). In the filter the back water is strained through a continuous felt cloth which is kept revolving by machinery and cleansed by a water spray. The save all is in the form of a truncated cone revolving on a central axis and covered with perforated copper, the back water being admitted into the interior of the cone at the narrow end and escaping through the perforations, while the pulp gradually falls to be discharged at the lower and wider end of the cone. In connection with these a filter press is generally used, so that the fibre is recovered in the form of a pressed cake. Fibre thus recovered is generally considered unsuitable for making high-class papers, and is often sold to other manufacturers who make coarser papers. In any case it must be looked upon as a raw material and passed through all the ordinary processes, and before it again reaches the paper machine there may be a change in the kind or colour of paper made, so that it cannot at once be re-used. An apparatus such as a stuff catcher or save-all is not sufficient to purify effectively the waters passed through it, and these must afterwards be treated like the rest of the refuse from the mill. If, however, they are passed into separate settling tanks, the sludge depositing from them may be pressed and returned to the mill to be used as raw material, as is done at the Darwen Paper Mill.

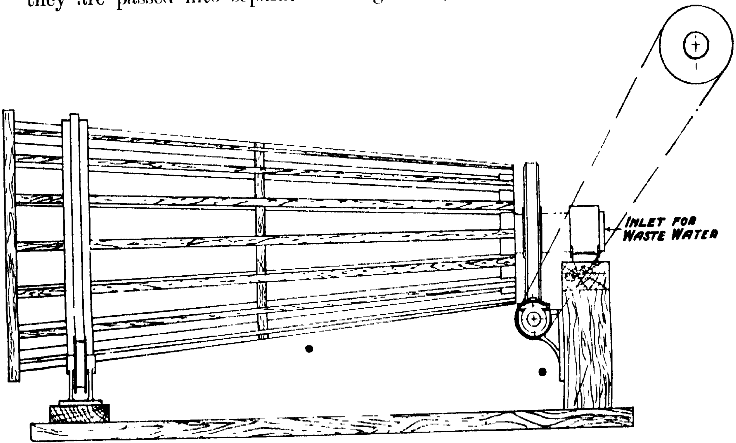

FIG. 14 -Conical Save All.

Wood-pulp Manufacture.—The use of wood pulp in the manufacture of paper is rapidly increasing, and its preparation is a cause of very serious river pollution, especially in America and Germany. There are two processes by which the cellulose of wood is prepared to be made into paper, the one a mechanical process and the other a chemical; but as there appears to be no manufacture of mechanical wood pulp in this country, it is unnecessary to describe the method of its preparation. Those interested will find it described in the text-books mentioned in the bibliography at the end of this chapter.

In the preparation of chemical wood pulp there are three processes ordinarily in use, in which caustic soda, sodium sulphate along with caustic soda, and calcium bisulphite along with sulphurous acid, are the reagents respectively employed. The last of these seems to be the process in use in this country, and that only in a very few instances.

In this sulphite process the wood is ground into small pieces by machinery, and boiled under considerable steam pressure in kiers, in a solution of calcium bisulphite charged with sulphurous acid. After boiling for many hours the kier liquor is drained off, the kier again charged with water and heated up by steam, and this first washing water drained away, and the washing process is repeated a second time. The wood pulp thus prepared is taken to the paper mill and made into paper, as has already been described.

The discharges from the sulphite process are thus divisible into three: the crude kier liquor containing the spent bisulphite and the organic matters which have been dissolved out of the wood, a brown, slightly turbid liquid with a strong, peculiar, and not unpleasant smell; and the first and second washings, which are similar liquids, but more dilute. The crude kier liquor and the first washings contain so much organic matter that they are very difficult to purify; the final washings can be mixed with the general refuse of a paper mill and purified along with it.

For dealing with the crude kier liquor and the first washings the only method to be recommended is a process of evaporation, like that suggested for the kier liquor from the boiling of esparto grass. If these liquids, which, as they are discharged, have a specific gravity of 1·040, are evaporated down until they reach a specific gravity of 1·300, the resulting treacly liquid can be used for various industrial purposes, such as sizing paper, tanning and dyeing, preventing dust on roads, and making small coal into briquettes. In this country the quantity of this kind of refuse is so small that the production scarcely meets the demand, and the price received more than pays for the somewhat costly evaporation process, but on the Continent and in America so much is produced that its utilisation forms a problem not yet solved. For every ton of paper pulp produced there is a discharge of nearly a ton of solids dissolved in the refuse water, so that the total waste of organic material is enormous. Many attempts have been made to utilise this waste, and recently it has been suggested that it should be used for the production of sugar and alcohol.

The methods of evaporation adopted are described in Chapter XI., and in this case it must be remembered that the liquid contains free sulphurous acid and many sulphur compounds, and acts very vigorously upon metals, so that the wear and tear of the evaporation plant is very great, and may amount to as much as 20 per cent. of its value annually.

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CHAPTER VII.

THE TEXTILE TRADES.

Classification of trade processes—Cotton bleaching—Kier liquor—Cotton-waste bleaching—Degreasing—Bleaching and retting of flax, hemp, and jute—Wool washing—Recovery of potash and grease—Improvements in grease recovery—Further treatment of effluent from soak tanks—Precipitation and biological filtration—Evaporation of wool suds (Smith-Leach apparatus)—Chambers and Hammond's process—Solvent processes of degreasing wool—Silk boiling.

UNDER this head may be grouped all the processes by means of which fibrous materials either of animal or vegetable origin are made into woven fabrics. The most important of these raw materials are cotton, wool, silk, flax, hemp, and jute, and the processes which they undergo yield waste waters which for the most part fall into two categories, the first comprising the liquids which result from the cleansing and preparation of the materials, the second those coming from the manufacturing and finishing processes. Refuse of the first kind, such as that from wool washing, silk boiling, and flax retting, contains much organic matter which has been extracted from the materials themselves, whereas the other kind of refuse owes its polluting character chiefly to the various reagents used, such, for instance, as oil, soap, fuller's earth, and dyewares.

Dealing first with the waste waters resulting from the preparatory processes, they may be considered under the following heads:—

1. Bleaching of vegetable fibres.
2. Retting of flax, jute, and hemp.
3. Wool washing.
4. Silk boiling.

The purification of liquids arising from these processes, since they contain large quantities of dissolved organic matters, must generally depend finally upon biological methods.

The secondary processes include:—

1. Dyeing and printing.
2. Stiffening and loading.
3. Carbonising and stripping.
4. Yarn washing and piece scouring.

For the most part, refuse from these processes can be purified by chemical precipitation and straining.

Cotton Bleaching.—Raw cotton as it reaches the spinner contains about 5 per cent. of impurities, which, if not removed, would impair the whiteness of the manufactured goods, and would interfere with subsequent dyeing and printing operations. These impurities, according to Dr E. Schunck, comprise:—

1. A cotton wax.
2. A fatty acid, which appears to be either margaric or a mixture of palmitic and stearic acids.
3. Nitrogenous colouring matters.
4. Pectic acid, which forms the greater bulk of the impurities.
5. Albuminous matter.

The raw cotton is usually spun into yarn or even woven into pieces before any attempt is made to get rid of the impurities. Further, in order to stiffen the fibre and to facilitate the weaving process, or in some cases to adulterate the goods, substances such as size and china clay are added to such an extent that they may form as much as 30 or 40 per cent. by weight of the woven goods. The object of bleaching is to remove all these natural and artificial impurities from the cotton fibre, either for the purpose of selling the goods in the white state, or in order to make them suitable for being dyed or printed.

So far as the polluting discharges are concerned, there is so little difference between the bleaching of cotton piece goods and cotton yarn that one description may serve for both. In the bleaching of cotton piece goods there are several processes in common use. In that most practised the various operations are:—

1. Grey washing.
2. Boiling with lime.
3. Treatment with weak acid.
4. Boiling with soda ash and resin soap.
5. Treatment with a solution of bleaching powder.
6. Treatment with weak acid.
7. Final washing.

1. In the "grey washing" the goods are passed through water, which removes some of the soluble matters. The wet goods after this washing are allowed to lie in a heap, when fermentation is set up, which renders the starchy matters soluble.

2. In the "lime boil" the goods are passed through milk of lime and packed in a "kier," a large iron or steel cylinder, in which they are heated by steam, sometimes under pressure. After the boiling, the lime liquor is run off and the kier filled with cold water and again emptied. The chief effect of the lime boil is to decompose the fatty and oily matters contained in the pieces, with the formation of lime soaps which adhere to the fibres. It also removes starchy and other soluble matters, and chemically changes other impurities, so that they are easily washed out afterwards. In some cases soda is used instead of lime, and has much the same effect. The

goods removed from the kier are washed in water to remove the impurities and as much of the lime as possible.

3. The goods are then passed through a weak solution of sulphuric or hydrochloric acid, the "first sour" or "grey sour." This decomposes the lime soaps on the fibre and dissolves metallic oxides and other mineral matters, which are then removed by another washing.

4. In the next process the goods are boiled, usually under pressure, in a solution of soda ash and resin, the "lye boil," and are then further boiled, either in a weak solution of soda or in water, to dissolve the resin soap, which is afterwards removed by a thorough washing. In this lye boiling the fatty acids are dissolved out by the alkali used, and the resin soap removes from the fibre some constituents which readily absorb colours. The resin, therefore, is chiefly used for goods which are to be printed, and in bleaching other goods is often omitted.

5. The next process is that of bleaching proper, or "chemicking." In it the goods are passed through a bleaching solution, prepared by mixing bleaching powder with water, allowing the solids to settle, and drawing off the supernatant liquid. After the chemicking the goods are washed in water, but are sometimes first piled in a heap so as to allow the bleaching agent time to act with the assistance of the carbon dioxide of the air.

6. In the "white sour" the goods are again passed through a weak solution of sulphuric or hydrochloric acid, which completes the bleaching process and dissolves the lime salts resulting from the use of the bleaching solution.

7. The goods are finally thoroughly washed in large volumes of clean water, and in the case of yarns this final washing is preceded by softening the yarn in a hot solution of soap.

The waste liquids discharged from these different processes vary greatly in character (see Table XXVII.). Much of the water used for washing is only slightly polluted and can be little improved by ordinary methods of treatment. It can, in fact, in many cases, be discharged to a stream without much detriment to the waters. But if this is done it needs great care on the part of the manufacturer in dividing his cleaner waters from the more polluted (see p. 199). By far the worst liquid is that which is discharged from the kiers, and this should be disposed of separately, and for this purpose various contrivances have been adopted. In some cases it is got rid of by pouring it into disused pits or by irrigating it upon land where it can percolate into the subsoil. If such simple methods of disposal are not available, then recourse must be had to special means. When a waste soda liquor is neutralised with sulphuric acid there is (see Table XXVIII.) a large precipitation of the contained solids and a great reduction in the oxygen-absorbed figure, which shows that much of the organic matter is removed, and after settlement, the resulting neutral liquid can be mixed and treated along with the rest of the bleach-croft refuse without difficulty. In the case of a lime liquor the effects of this

TABLE XXVII.

REFUSE FROM BLEACHING OF LIGHT COTTON GOODS.

(*Results expressed in parts per 100,000.*)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Alkalinity (as Na_2CO_3).	Acidity (as H_2SO_4).	Free Chlorine.	Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Total.	Filtrate.				Total.	Permt.	Tempy.
Lime boil	560·2	71·6	23·3	488·6	102·0	0·17	1·27	4·31	42·46	40·12	76·3	...	...	...	...	...
Wash after lime boil	63·6	14·1	2·4	49·5	15·3	nil	0·19	0·50	4·30	1·59	...	...	...	13·9	8·3	5·6
Soda-ash boil	372·3	42·8	4·8	329·5	218·0	trace	0·42	1·31	18·94	17·16	173·8	...	...	1·8	1·4	0·4
Wash after soda-ash boil	75·6	15·7	2·6	59·9	37·9	trace	0·10	0·26	3·14	2·51	26·5	...	...	6·1	0·6	5·5
Grey chemic	281·3	2·1	1·0	279·2	180·2	0·05	0·31	1·57	2·86	2·86	13·8	...	...	178·5	150·0	28·5
Wash after grey chemic	63·5	9·1	1·4	54·4	21·4	0·00	0·04	0·34	0·98	0·60	5·3	...	...	23·6	22·7	0·9
Grey sour	153·5	0·7	0·6	152·8	86·4	0·03	0·12	0·31	3·22	3·06	...	35·3	...	107·6	102·8	4·8
Wash after grey sour	31·1	3·7	1·6	27·4	22·0	0·00	0·03	0·13	0·46	0·40	...	2·45	...	15·7	15·3	0·4
Wash after white chemic	71·1	6·5	3·1	64·6	27·2	0·00	0·00	0·02	0·16	0·10	9·0	...	11·09	36·0	28·4	7·6
Wash after white sour	16·7	0·7	0·6	16·0	10·6	0·00	0·00	0·02	0·10	0·04	...	0·49	...	9·4	7·7	1·7
Mixed refuse passing to tanks	85·8	21·8	7·3	64·0	26·0	0·00	0·06	0·39	2·12	1·64	4·8	...	0·36	24·8	23·3	1·5
Final effluent	69·0	6·6	2·6	62·4	30·0	0·00	0·12	0·41	1·42	1·04	12·7	...	...	31·6	21·2	10·4

acid treatment are much less marked, but instead of sulphuric acid, carbon dioxide or flue gases could be used.

But perhaps the best method of dealing with the kier liquor is by concentration and evaporation. When a soda lye is used in the kiers it still contains after the boiling a large amount of unexhausted soda, besides that which is combined with organic matters extracted from the materials, and this soda is recoverable by the same method as that used for the boilings of esparto grass (p. 88). The strength of the lye in this case is considerably less than that in the paper-trade refuse, but the recovery of soda will at least go a long way towards paying for the cost of the process. In some cases, moreover, it is possible to use the spent lye a second time, strengthening it by the addition of further quantities of soda, and thus to obtain an alkaline liquid sufficiently strong to make its evaporation profitable, or this object can be to some extent attained and the polluting discharges lessened by using the first washings from one kier to make up the lye for the next. The necessary apparatus for evaporation and the method of its use will be found described in Chapter XI. Where a lime boil is used there is obviously no return to be expected from an evaporation process, but in such cases it may be found advantageous to use soda instead of lime, or the kier liquor may be precipitated with sulphuric acid before being mixed with the rest of the refuse (see Table XXVIII.).

TABLE XXVIII.

EFFECT OF ACID ON KIER LIQUORS.

(*Results expressed in parts per 100,000.*)

Sample from	Solids in Suspension (dried at 100° C.)	Oxygen absorbed by Filtrate from $\frac{N}{80}$ permanganate in four hours at 26·7° C.
First soda boil from bleaching cotton waste	638·0	2775·0
Do. after adding acid . . .	3463·0	1314·9
Second soda boil from bleaching cotton waste	80·0	802·0
Do. after adding acid . . .	745·6	440·0
Lime boil from bleaching light cotton goods	71·6	40·1
Do. after adding acid . . .	31·4	35·4
Lime boil from bleaching light cotton goods	6·9	50·4
Do. after adding acid . . .	16·5	50·2
Soda boil from bleaching light cotton goods	42·8	17·2
Do. after adding acid . . .	81·0	9·2

Where for any reason no separate treatment of the kier liquor is adopted, it should be stored up to be discharged so as to mix gradually with the rest of the bleach-croft refuse. If this is not done the sudden rushes of strongly alkaline liquor will be certain to upset any method of treatment.

If the kier liquor is dealt with separately, as above suggested, the treatment of the refuse from a bleach croft is not a difficult matter. Such a liquid, as has already been suggested, lends itself to purification by biological methods because of the organic matter it contains.

Mr W. Naylor, A.M.I.C.E., in his book on *Trades' Waste*, describes works for the purification of bleach-croft refuse both by means of contact beds and percolating filters, and states that he obtained good results by both methods. These works are still in use, but, as the area of filters is too small to deal properly with the volume of refuse passing through them, the results obtained are more the effect of simple straining than of biological action. In order to render the refuse more susceptible to biological treatment, Mr Naylor kept it in a tank to which septic sewage sludge was added from time to time; but this seems scarcely necessary, as the refuse kept by itself soon becomes septic and evolves sulphuretted hydrogen. It is, in fact, now generally held that such liquids should not be allowed to become septic before being applied to biological filters. The addition of the sewage sludge, however, may have the effect of introducing organisms which play an important part in the destruction of the organic matters in the refuse.

In the 1906 Report of the State Board of Health of Massachusetts it is stated (p. 301) that mixed refuse from a bleach croft can be dealt with by sedimentation, followed by filtration through three feet of sand at a rate of 50,000 gallons per acre daily, with the production of an effluent showing 91 per cent. purification as determined by the oxygen absorbed.

Laboratory experiments bear out the above conclusions, for on applying a settled mixture of the various discharges, including a more than proportional amount of strong kier liquor, to the filter described on p. 117, an effluent was produced (see Table XXIX.), showing nearly 60 per cent. of purification when judged by the oxygen-absorbed figure, containing large amounts of nitrates, and remaining inoffensive and stable on incubation. The liquid was applied to the filter at the rate of 33 gallons per cube yard per day, the whole being applied during eight hours out of the twenty-four. A second filtration of this effluent produced little further purification.

From the foregoing examples it is abundantly evident that these bleach-croft liquids are amenable to biological treatment, and the best method of dealing with them appears to be the separate disposal of the kier liquors, the mixture and settlement of the other discharges in tanks such as are described in Chapter XI. (the tank treatment can be much assisted by the use of a chemical precipitant), and the distribution of the settled liquor upon a percolating filter, such as is described on p. 269, at a rate

TABLE XXIX.

FILTRATION OF BLEACH-CROFT REFUSE.

(*Results expressed in parts per 100,000.*)

	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.				Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Nitric.	Total.	By Filtrate.	Total.	Permt.	Tempy.
Mixed refuse settled.	481·0	29·2	3·5	451·8	252·8	0·13	4·21	9·89	...	79·0	70·8	29·7	12·0	17·7
Settled refuse filtered once . . .	326·7	8·5	2·4	318·2	210·2	0·04	1·89	4·70	4·55	34·7	33·8	13·8	8·7	5·1
Settled refuse filtered twice . . .	347·1	4·1	1·3	343·0	218·4	0·06	1·71	4·59	6·67	34·2	34·1	4·6	4·0	0·6

not exceeding 100 gallons per cube yard per day. It may also be necessary to provide straining filters or secondary tanks for the removal of suspended matter from the percolating filter effluent.

These biological methods recommended above do not seem to have been brought into use on a sufficient scale at any bleach croft; the treatment carried out is usually settlement of the mixed refuse, sometimes aided by precipitation with alumino-ferric, followed by straining through filters of cinders or clinker; but this does not appear to give a really satisfactory result in any case, and there are few bleach crofts of any importance which do not injuriously affect the streams into which their refuse is discharged.

As examples of the kind of refuse produced in cotton bleaching and the effect of its treatment by settlement and straining, the analyses in Table XXVII. are given. The total daily flow of refuse at the bleach works where these samples were taken is about 75,000 gallons, of which the larger proportion, consisting of the washing waters, is discharged direct to the stream. The more polluting part of the refuse is received into a sump of 18,400 gallons capacity, from which it is pumped by means of a steam injector into two settling tanks, each holding 4500 gallons. These overflow on to two cinder filters, each of 16 square yards area, and a sludge filter is provided for receiving the sludge which settles in the tanks. A plan and section of these works are given in Fig. 15.

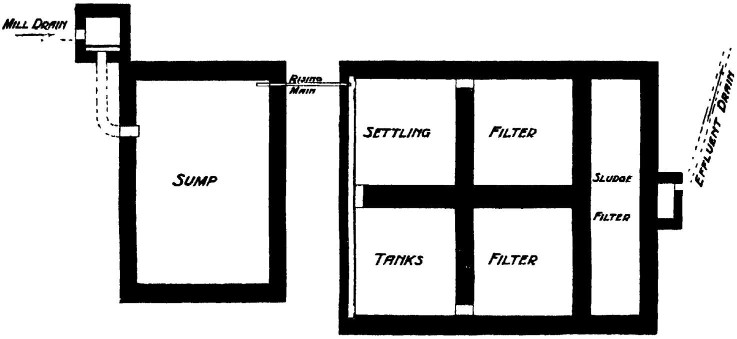
In this case the quantities of the various liquors discharged from bleaching 1000 lbs. of cloth are:—

Lime boil	400	gallons.
Spent chlorine liquor	60	,,
Spent acid	60	,,
Soda-ash boil	400	,,
Washing waters	14,080	,,
Total . .	15,000	,,

Although no provision is here made for treating the kier liquor separately or discharging it gradually so as to mix uniformly with the rest of the refuse, the latter object is to a great extent attained by the mixing which takes place in the comparatively large sump.

Cotton-Waste Bleaching.—An important industry in the cotton districts is that of bleaching cotton waste, which is afterwards made into gun-cotton. The raw material of this industry consists of the cotton fibre swept from the floors of spinning mills, and of the cotton waste which has been used for cleansing machinery. It is thus extremely dirty, containing sometimes 30 per cent. of impurities, and of these, half, or more, may be oil or grease which has been wiped off the machinery.

The processes of bleaching cotton waste are practically the same as those already described for dealing with cotton piece goods, but the grease present raises special difficulties and may cause much more polluting discharges, if only the ordinary processes are employed. In the best equipped mills the cotton waste is first degreased by being treated in closed iron vessels with a grease solvent, such as petroleum naphtha. The solution of grease is afterwards distilled to separate the solvent from the grease, the former being re-used and the latter sold as a bye-product. This process is fortunately quite a profitable one, besides rendering the after process of bleaching much easier and the final discharges much less polluting.



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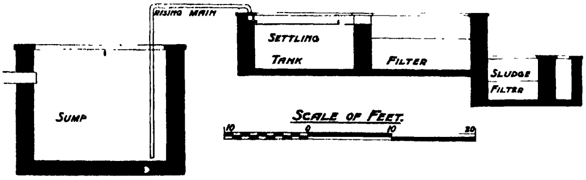


SECTION.

FIG. 15.—Works for the Purification of Refuse from Cotton Bleaching.

For the degreasing of such materials as cotton waste by a solvent process several forms of apparatus are in use. The new process described on p. 125 in connection with the degreasing of wool is equally applicable to cotton waste, and is probably the most economical and most complete. The usual process is described in Chapter X., p. 211, as applied to the degreasing of sludge cake.

The grease in cotton waste can also be extracted by the aid of steam in the Turbine Centrifugal Fat Extractor of the Industrial Waste Eliminators, Ltd., 20 High Holborn, London. Their machine is in the form of a centrifugal drier such as is found in most textile factories. It is driven by a steam turbine, and the exhaust steam is made to permeate the greasy material. By centrifugal action the grease liquefied by the steam is driven to the periphery, where it is collected. In dealing with greasy mill cloths it is stated that only 2 per cent. of grease is left in the cloths after treatment in this apparatus.

The degreased cotton is freed from the last traces of solvent by means of superheated steam, and is then thoroughly washed with water and afterwards with weak acid, boiled with soda ash, washed, chemicked, soured, and finally washed. Large volumes of water are used in all the washing processes, which are carried on in "beaters" similar to those used in preparing paper pulp.

Even after a degreasing process the combined refuse from cotton-waste bleaching (see Table XXX.) is much more polluting than that from an ordinary bleach croft, inasmuch as the raw material contains a great deal of filth which is not present in raw cotton. The worst discharge is that from the kiers, which should, as already suggested, be treated separately. In the discharges from the repeated washings a great deal of loose cotton fibre escapes, and this it is found highly profitable to recover by the aid of screening apparatus, such for instance as that shown in Figs. 41, 42, and 43. Its amount may be as much as 2 per cent. of the raw material, and if not recovered it adds considerably to the difficulties of purification, especially by increasing the amount of sludge produced.

The further purification of the refuse may be effected by the same means as are employed for that of an ordinary bleach croft (see p. 101), provided, that is, that the degreasing process is first adopted, and this should always be insisted upon.

Table XXX. gives the analyses of the various discharges from cotton-waste bleaching at a mill provided with an up-to-date solvent plant for the extraction of grease. It shows also the results of simple settlement of the mixed refuse. In this case the quantities of the various discharges from the bleaching of 1000 lbs. of waste are approximately as follows:—

Kier liquor	360	gallons
Spent chlorine liquor	3,800	„
Spent acid	3,800	„
Washing water	16,040	„
Total	24,000	„

Flax, Hemp, and Jute Bleaching.—The bleaching of these materials, whether in the yarn or the piece, is essentially the same as the process used for cotton. It is, however, longer and more tedious, and the various processes, boiling, chemicking, and souring, must be repeated several times before a satisfactory white is obtained. The raw materials contain a greater proportion of impurities than raw cotton; for whereas ordinary raw cotton only contains about 5 per cent. of foreign matter, linen when fully bleached loses as much as 20 per cent. of its weight.

TABLE XXX.

REFUSE FROM COTTON-WASTE BLEACHING.

(*Results expressed in parts per 100,000.*)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Alkalinity (as Na_2CO_3)	Acidity (as H_2SO_4).	Free Chlorine.	Hardness (in terms of $CaCO_3$)		
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Total.	Filtrate.				Total.	Permt	Tempy
Wash after degreasing . .	34·6	15·2	6·2	19·4	10·6	0·00	0·10	0·36	2·65	0·98	...			12·9	6·0	6·9
Acid wash after degreasing . .	205·6	2·7	0·3	202·9	45·5	0·00	0·19	0·50	4·12	4·04	.	142·1	...	276·3	221·0	55·3
First kier liquor .	12964·8	638·0	...	12326·8	4590·8	11·90	266·00	434·80	2779·50	2775·00	1908·0	. .	...		. .	...
Second kier liquor .	5294·8	80·0	...	5214·8	3018·8	3·20	33·20	66·20	806·00	802·00	2438·0	...	...	...	...	...
Wash after kiers .	144·0	58·4	26·4	85·6	52·0	0·05	0·32	0·66	11·03	9·17	40·3	...	...	4·4	2·6	1·8
Chemic and sour .	419·3	0·5	0·5	418·8	165·6	0·00	0·01	0·04	0·39	0·39	. .	264·6	4·08	643·0	507·5	135·5
Wash after chemic and sour . .	22·6	4·0	1·4	18·6	8·2	0·00	0·01	0·04	0·32	0·32	.			11·1	6·6	4·5
Mixed refuse with kier liquor . .	289·4	122·8	39·1	166·6	105·0	0·13	1·02	2·11	26·06	20·20	79·5			4·4	2·9	1·5
Mixed refuse without kier liquor .	98·8	46·6	16·3	52·2	24·0	0·00	0·44	1·14	7·90	4·46	22·3	...	...	19·1	4·6	14·5
Final effluent .	51·1	7·3	3·2	43·8	17·0	0·07	0·19	0·61	4·59	3·46	16·9	. .	...	13·2	3·0	10·2

The liquids discharged are very similar to those mentioned in connection with cotton bleaching. The most polluting discharges are the kier liquors and first washing waters, which in this case contain very much larger proportions of dissolved organic matter. These liquids should be strengthened by the addition of more soda, the alkali generally used, should be concentrated by re-use, and finally evaporated to dryness and incinerated for the recovery of the soda (see p. 275). The refuse from the other processes can then easily be purified like that of the ordinary bleach croft, especially if chemical precipitants are used.

In bleaching these vegetable fibres various other reagents are at times used in place of chlorine, such as permanganate of potash, bisulphites, and perborates, but any resulting refuse is easy to purify in comparison with the liquors from the ordinary process.

Retting of Flax, Hemp, and Jute.—Although the manufacture of textile fabrics from flax, hemp, and jute is a very important industry, the plants from which the materials are obtained are seldom grown in this country. Where they are grown, the process of "retting," or separating the crude fibres from the plant as harvested yields liquid refuse of a highly polluting character. Bundles of the plants are steeped in water for a week or two, when a fermentation takes place of the pectose in the cells which bind the bast fibres together, the active agents being certain species of bacteria. This fermentation is accompanied by the solution of much organic matter, producing a liquid which has a very offensive smell and which is capable of causing intense pollution if discharged into a stream. Retting is almost invariably done on the farms where the crops are grown, so that it is a comparatively easy matter to dispose of the refuse by irrigation upon land; it has indeed valuable manurial properties.

Wool Washing.—Wool as it is removed from the sheep's back contains a considerable proportion, often over 50 per cent., of material other than wool fibre. This material consists in great part of animal secretions, but also of sand and dirt, together with vegetable matters which mechanically adhere to the wool. Before the wool can be utilised it must undergo a washing process, in which the foreign materials are removed by the aid of water and soap, soda, or other detergents.

The animal secretions are known as "yolk" (French, "suint"), and are partly soluble in water and partly insoluble. The soluble matters are mainly the potash salts of oleic acid and other fatty acids, such as lanopalmic and capric, and when greasy wool is washed in water these potash salts, which are of a soapy nature, cause the "wool grease" or "wool wax" to emulsify, so that it can be more easily washed out of the fibre. The wool grease, which is insoluble in water, appears to consist mainly of various esters of cholesterol, isocholesterol, ceryl alcohol, and carnubyl alcohol, with oleic, lanopalmic, lanoceric, carnubic, and other acids. Some glyceride of myristic acid has also been isolated, and it is probable that free cholesterol and isocholesterol are also present.

The raw wool used in the wool trade varies very much in the condition in which it reaches the manufacturer. "Greasy wool" from the Cape, Australia, and the Argentine, is used to a great extent, and this may contain over 50 per cent. of impurities, including as much as 15 to 25 per cent. of grease, 6 to 7 per cent. of potash salts, and 3 to 24 per cent. of sand and dirt. Occasionally this wool is washed in the country of its origin in order to lessen freightage charges, and this practice is constantly increasing. The wool which has thus been treated is bought as "scoured wool," but still contains sufficient grease and impurities to render a further washing necessary. "Home-bred wool" never contains so much extraneous matter as the unscoured foreign wools. It generally loses only some 20 to 22 per cent. of its weight when washed, of which from 7 to 10 per cent. may be grease. "Slipe" or "skin wool" is that which is removed from the skin of the dead sheep, and when removed by the fellmonger or tanner most of it is known as "lime wool," since it contains considerable amounts of the lime used in the ordinary process of unhairing (see p. 72). This lime is in combination with much of the natural grease of the wool, and has displaced the potash which was originally present. These different kinds of wool are now very frequently blended before they are washed, when the proportions of grease, potash, and sand present vary according to the kinds of wool present in the mixture. Other materials used in the wool trade include mohair, alpaca, and camel's hair, but these contain comparatively small amounts of greasy matter or potash, although at times they may be exceedingly dirty.

The process of wool washing is usually carried on in a set of three or four Petrie or M'Naught wool-washing bowls. These are long tanks, each containing 500 to 1760 gallons of water at a temperature of about 40° to 50° C. They are used in series, the wool being passed consecutively from the first to the last, and to the first bowl detergents, such as soap and soda, are added from time to time. The water used for washing, on the other hand, is passed backwards consecutively from the last to the first, so that the dirty water is finally discharged from the first bowl, and is therefore all of a very polluting character, and approximately uniform in composition. In one case where greasy wool was being washed, every 100 lbs. of wool required 14 gallons of water, and a little over 2 lbs. of soft soap. In other cases, however, it is estimated that 100 gallons of water are required for washing 100 lbs. of wool.

In small mills the wool-washing process is often carried out in a somewhat different manner. The wool is placed in a perforated vessel within a vat filled with water, and soap, soda, or some other cleansing material is added. Stale urine or pigs' dung and even human excrement were formerly commonly used as detergents, although now less often. The water is heated and the wool stirred about from time to time, being finally drained and transferred in the perforated vessel to another vat to be washed repeatedly with clean water. The soapy contents of the first vat are usually stored up and re-used until they become impregnated with grease and dirt, or too putrid to be used, when they are discharged and the cistern is made up afresh. The discharges from this wool-washing process, therefore, vary greatly, including the very foul and often putrefying liquid from the steeping tank, and the successively cleaner washing waters. The amount of water used in this way is difficult to estimate. In the Third Report of the 1865 Commission (p. 24), it is given at 224 gallons to 100 lbs. of wool in each washing, of which there are two or more. This process is never found in use in a mill which is entirely given over to wool combing, so that the refuse produced by it generally requires to be purified along with other kinds of refuse, such as that from piece scouring and dyeing.

In a wool-combing mill the wool, after leaving the washing bowls, is dried by being squeezed between rollers and generally also by being passed through a hot-air chamber. It is then prepared for carding by the addition of some 0·05 per cent. of olive oil. After carding it undergoes the process of "backwashing," which is a secondary rinsing in soapy water of the "slivers" or loose untwisted ropes of wool produced in the carding process. The soapy water removes the oil, but takes up very little dirt, as this has been previously scoured out of the wool. The water used in backwashing is usually less than one-tenth of the quantity which escapes from the wool-washing bowls, and is not nearly so polluting in character. The two are generally discharged and treated together.

The refuse from wool washing is a brown, thickly turbid liquid, often covered with a greasy, frothy scum, and yielding a considerable deposit of mineral matter on standing. It is strongly alkaline in reaction, has a peculiar smell even when fresh, and soon becomes very offensive from putrefaction. Analyses of such liquids are given in Table XXXI. The first two sets of samples were taken from mills where mixed wools—greasy Colonial, home-bred, and skin wools—were being scoured at the time; the third set of samples came from a mill where only greasy Colonial wools were being scoured.

In this refuse there are two valuable bye-products which, if recovered, will more than repay the cost of the purification process. The first of these is the potash, which may yield (see Table XXXV.) one ton of carbonate of potash from 55,000 gallons of refuse. The ordinary process for recovering the potash is to pass water repeatedly through the raw wool until it has dissolved out a sufficient amount of potassium salts to make an evaporation process profitable. After this solution of potassium salts has been evaporated down sufficiently, it is passed into a revolving cylindrical incinerator (Fig. 66) and ignited, with the production of crude carbonate of potash. This is the process generally adopted where wool is scoured with soap in the usual way, but in solvent processes for cleansing wool, and in the methods of dealing with wool suds adopted by Messrs Chambers and Hammond and by Mr Leach, and described later, an

TABLE XXXI.

WOOL SUDS AND EFFLUENTS FROM GREASE RECOVERY.

(Results expressed in parts per 100,000.)

Nature of Sample.	Solids.		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Nitrogen.		Fatty Matter.			Alkalinity (in terms of K_2CO_3).		Potash (in terms of K_2CO_3).	Acidity (in terms of H_2SO_4).	Precipitants Added.			Sludge Produced. Per Cent. of Total Volume.	Cost of Precipitants per 1000 Gallons (Pence).
	Total (dried at 100° C.).	Ash.		Ammoniacal.	Organic (Kjeldahl).	Total	Unsaponifiable.	Percentage Unsaponifiable.	Total	In Ash.			Lime to Neutralise.	Lime to Precipitate.	Ferric Sulphate.		
Wool suds, including backwashing water (average of six) .	2388·3	853·0	213·4	16·2	33·5	834·6	316·3	37·8	543·3	419·7	417·7	...	...	...	...	...	..
Effluents from grease plant (average of six)	1755·8	857·0	153 0	9·0	24·2	354·0	109·7	31·7	..	...	...	73·5	84·8	197·5	358·3	24·7	8·0
Wool suds, including backwashing water (average of six) .	2466 6	785·3	215·5	9·1	23·8	1018·9	361·3	35·1	540·4	368·0	308·9	.	...	..	...	...	...
Effluents from grease plant (average of six)	1306·0	716·8	111·6	3·9	15·8	174·3	50·2	26·9	...	...	...	114·3	93·4	187·5	200·0	16·3	5·5
Wool suds, including backwashing water (average of four) .	3387·9	967·8	149·1	19·6	39·4	1799·5	...	...	407·7	..		...	...	..	...	...	...
Effluents from grease plant (average of two)	1290·2	876·4	62·3	21·9	12·1	42 7	...	...	...	..	...	37·7	...	...	...	...	...
Backwashing water (average of two) .	842·7	113·6	36·2	1·9	8·7	517·6	...	...	41·5	...	...	...	...	...	...	...	...

aqueous solution of the potash salts, comparatively free from grease, is incidentally obtained, so that this preliminary soaking of the wool in water is not necessary. In practice, however, all this valuable potash is almost invariably wasted and allowed to escape down the mill drains.

The other valuable bye-product is the grease, which is almost invariably recovered by treating the wool suds with acid and pressing the grease out of the deposited sludge by the aid of heat. The *battage* process for its recovery was for a time advocated, but now seems to have been abandoned in this country. The suds were beaten up by revolving paddles so as to cause the grease to form, on the surface of the liquid, a froth which could be skimmed off. The grease was not thoroughly removed, and the effluent was even more polluting than that from the ordinary acid process.

The Rivers Pollution Commission of 1865, in their Third Report, dealing with the Rivers Aire and Calder, mention in some detail the pollution caused by the discharge of wool-washing refuse (p. 22), and the acid method for the extraction of grease (p. 27). They gave their opinion of this in the following words (p. 31):—

> "Our own experience is not in favour of the success of this method of clearing the water. It has not been our fortune to see any instance of this process being carried out with the result of 'very clear' effluent water. On the contrary, in the examples which we have seen, the appearance of the liquid has not been sensibly affected by the treatment, and the water has escaped foul and objectionable. When the liquid passes away foul and uncleansed we may take it for granted that grease is being wasted."

They gave certain suggestions for the better purification of this class of refuse (p. 33), and one or two of these suggestions have occasionally been adopted by manufacturers, but until the last few years the old process, almost unaltered, was in use at the majority of mills. The works erected for the recovery of the grease were frequently grossly neglected and allowed to become dilapidated. The management was generally not in the hands of an employee of the manufacturer, but given over to a grease extractor, whose aim it was to make a profit out of the grease recovered, without the least care as to the effluent, and in very numerous cases this management was so slovenly, that, as the Royal Commission pointed out, great quantities of grease were wasted by being discharged into the streams. Samples of the effluents from such works bear this out (see Table XXXI.).

It will be noted that in the table an average figure is given for the acidity, but some samples were found to be alkaline in reaction, and had to be acidified in the laboratory before the grease could be estimated. Such cases clearly show carelessness of management, as the grease cannot be separated without making the liquid acid. In the first two instances the analyses show the loss of grease which may occur in this process, 40 per cent. in one case, and 17 per cent. in the other, of the total grease present in the crude suds being allowed to escape in the effluent.

The following is a description of one of the very best of the grease extraction works on the old system, with the results of treatment under

TABLE XXXI.

WOOL SUDS AND EFFLUENTS FROM GREASE RECOVERY.

(*Results expressed in parts per 100,000.*)

Nature of Sample.	Solids.		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Nitrogen.		Fatty Matter.			Alkalinity (in terms of K_2CO_3).		Potash (in terms of K_2CO_3).	Acidity (in terms of H_2SO_4).	Precipitants Added.			Sludge Produced. Per Cent. of Total Volume.	Cost of Precipitants per 1000 Gallons (Pence).
	Total (dried at 100° C.).	Ash.		Ammoniacal.	Organic (Kjeldahl).	Total	Unsaponifiable.	Percentage Unsaponifiable.	Total	In Ash.			Lime to Neutralise.	Lime to Precipitate.	Ferric Sulphate.		
Wool suds, including backwashing water (average of six) .	2388·3	853·0	213·4	16·2	33·5	834·6	316·3	37·8	543·3	419·7	417·7	...	...	...	...	...	..
Effluents from grease plant (average of six)	1755·8	857·0	153 0	9·0	24·2	354·0	109·7	31·7	..	...	...	73·5	84·8	197·5	358·3	24·7	8·0
Wool suds, including backwashing water (average of six) .	2466 6	785·3	215·5	9·1	23·8	1018·9	361·3	35·1	540·4	368·0	308·9	.	...	. .	...	...	...
Effluents from grease plant (average of six)	1306·0	716·8	111·6	3·9	15·8	174·3	50·2	26·9	...	...	...	114·3	93·4	187·5	200·0	16·3	5·5
Wool suds, including backwashing water (average of four) .	3387·9	967·8	149·1	19·6	39·4	1799·5	...	...	407·7	..		...	...	. .	...	...	...
Effluents from grease plant (average of two)	1290·2	876·4	62·3	21·9	12·1	42 7	...	...	...	..	...	37·7	...	...	...	...	...
Backwashing water (average of two) .	842·7	113·6	36·2	1·9	8·7	517·6	...	...	41·5	...	...	...	...	...	...	...	...

TABLE XXXII.

WOOL-WASHING REFUSE BEFORE AND AFTER TREATMENT.

(Results expressed in parts per 100,000.)

Average Sample of	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Alkalinity (as Na_2CO_3).	Acidity (as H_2SO_4).	Hardness. (in terms of $CaCO_3$).			Fat after Acidification.
		Total.	Ash.	Total.	Ash.	Ammoniacal	Albuminoid (Wanklyn)	Organic (Kjeldahl).				Total.	Permanent.	Temporary.	
Crude refuse (including backwashing water)	3387·9	2104·6	340·3	1283·3	627·5	19 63	10·06	39·41	149·15	312 7	..	216·3	84·3	132·0	1799·5
Backwashing water	842 7	697·9	49·8	144·8	63·8	1·90	0·82	8·72	36·25	31·8	...	98·0	25·1	72·9	517·6
Crude refuse settled	2203·5	1462·4	253·7	741·1	370·3	18·65	...	15·15	83·70	large	...	63·7	0·0	63·7	1276·0
Seak tank effluent	1290·2	47·5	20·0	1242·7	856·4	21·98	3·90	12·11	62·30	...	37·7	281 2	209·0	72·2	42·7
Magma filter effluent	1356·5	26·6	1·6	1329·9	881·2	22·01	3·17	11·13	58·15	..	69·8	257·1	...	...	32·3
Water and grease from presses	...	...	...	...	..	...	...	...	...	...	26·9	...	...	...	13043·5
Water from presses	685·0	195·6	5·6	489·4	231·4	8·80	...	13·60	33·60	...	8·8	114·3	...	...	133·5
Refuse from purification of grease	7824·0	121·6	...	7702·4	560·0	15·70	...	29·60	66·30	...	6270·0	..	...	...	105·2
Final effluent	1120·8	20·0	5·0	1100·8	765·6	18·22	3·96	14·34	55·74	...	35·3	191·7	187·0	4·7	23·7

bags of sacking, and pressed in a steam-heated press, worked by hand. Some 4½ tons of magma in the puddings are dealt with weekly. The expressed oil and acid liquid are separated by settlement in a small tank, from which the oil is skimmed off. The oil is afterwards purified by being treated with sulphuric acid, heated with steam, and again allowed to settle in a tank, from the bottom of which the impure acid water is drawn off. Both these acid liquids are passed through the final top-water filter; they ought to be run into the storage tank with the crude suds so as to make use of the acid they contain.

The total cost of the whole plant has not been more than £550. Steam is provided by the manufacturer, who estimates its cost at some £25 per annum. The management of the plant is in the hands of a grease extractor, who provides sulphuric acid and labour, and pays the manufacturer a rent of £80 per annum. It will be seen, therefore, that the manufacturer gets a fair return on his capital outlay.

Samples of crude refuse and of the effluents have several times been taken, and analyses are set out in Table XXXII. When these samples were taken, greasy Colonial Merino wool was being washed, containing 52 per cent. by weight of moisture, grease, and dirt, before washing, and yielding 48 per cent. of clean wool.

On examining the analyses of the final effluents to the stream, it will be seen that they are still very impure liquids, much worse than any sewage effluent which would be considered satisfactory.

Comparing these results with those obtained in the first two cases shown in Table XXXI., it is apparent that the quantity of grease which escapes in this case is comparatively small. This is due in great part to the better care exercised, and also to the proportionately large tank capacity, which allows time for thorough cooling and settlement, for it is found that when the acid is added to the hot suds the grease does not separate so completely as when the suds are previously cooled.

In Table XXXIII. are given analyses of the solids recovered at these works. It may be noted that the percentage of grease remaining in the pressed cake is very high, and, as will be described later (p. 211), a subsidiary trade has sprung up for the recovery of grease from such magma cake by a solvent process.

Recently several improvements in the working details of this process of grease extraction have been brought into use, with the result that a much greater percentage of the grease is recovered now than formerly, and at the same time less acid is used, so that the process is more economical, and the effluents, although still grossly polluting in character, are freed from large quantities of grease which formerly escaped into the streams. The acid, for example, is now frequently added to the suds as they run into the "seak" tank. When a tank is nearly full its contents can be tested, and a little more of the acid or of the suds added according to the alkalinity or acidity. In the older plants the mixing of the acid and suds was effected by stirring the contents of the tank with a long pole on the end of which a flat board was nailed. Now, in nearly every case some form of mechanical stirrer is used; either a set of mechanically driven paddles is fixed within the tank, by means of which the contents are agitated, or a current of air is forced through the liquid by an air compressor or steam injector. By the above improved methods the amount of acid used is often reduced 20 or 30 per cent. Sometimes fine sand, clay, or flue dust is added along with the acid with a view to entangling the particles of grease, and causing them to settle more perfectly.

The method of discharging the acid liquid after the separation of the grease has also been improved. In the older works this was effected by means of a series of holes in the wall of each tank, fitted with wooden plugs which were withdrawn one by one at the discretion of the man in charge of the works. Now the discharge pipe is generally fitted with an elbowed pipe inside the tank, which can be lowered to let off the acid water without letting the grease escape. Another contrivance has been brought into use for preventing this escape. The inner end of the discharge pipe is carried up inside the tank to a height just above the usual depth of sludge obtained, say 9 inches, and over this is placed a metal sleeve having numerous longitudinal slots some $\frac{7}{16}$ inch wide on the outside, but narrowing to $\frac{3}{16}$ inch on the inside. Such an apparatus has been used for a long time to separate cream from milk, and has now been adopted for the above purpose by Sir James Roberts at Saltaire Mills, and is shown in Fig. 17.

TABLE XXXIII.

SLUDGES FROM TREATMENT OF WOOL-WASHING REFUSE.

(*Results expressed in parts per cent.*)

Sample of	Moist Sludge.			* Dry Solids.				
	Moisture.	Organic and Volatile Matter.	Ash.	Organic and Volatile Matter.	Ash.	Nitrogen (Kjeldahl).	Siliceous Matter.	Total Fatty Matter.
Sludge from preliminary settling tanks .	36·98	6·81	56·21	11·11	88·89	0·55	81·36	5·02
Magma from top-water filter . .	83·73	...	...	...	...	...	...	67·48
Magma from magma filter . . .	58·50	34·30	7·20	82·65	17·35	1·47	...	67·42
Seak press cake .	23·96	51·68	24·36	67·96	32·04	2·46	22·69	37·87

* The figures are calculated from an analysis of the moist sludge.

In dealing with the deposited grease or magma a considerable improvement has been introduced by Mr J. Garfield at the Sewage Works of the Bradford Corporation, and is now used at several mills. The magma, instead of being run into filters and afterwards made into puddings, is pumped directly into filter presses such as are mentioned on p. 267, and are to be found in use at many sewage works, and there it is heated by steam and pressed so as to expel the grease and water. This does away with the necessity for magma filters and the labour and cost of making the puddings.

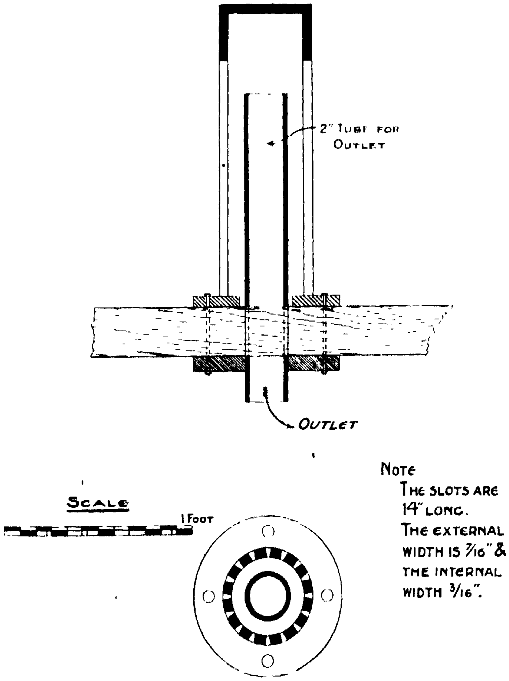


Fig. 17.—Contrivance for preventing the escape of Grease.

From the results given in Tables XXXI. and XXXII. it is evident, however, that the process is incapable of producing a satisfactory effluent. At the best this will be a strongly acid liquor, for a considerable excess of acid is required to separate the grease thoroughly. It is also highly charged with dissolved organic matters, which are very putrescible immediately the excess of acid is neutralised. Such a liquid, acid in reaction and still containing considerable amounts of grease, cannot be satisfactorily dealt with by biological methods alone, since the acid checks bacterial action and the grease clogs up the filtering material.

By using lime to neutralise the acidity and then adding a further quantity along with ferric sulphate to precipitate organic matters, and by provision of settling tanks for the deposition of the resulting solids, a tank effluent can be obtained which experiments have shown can be effectively purified either on an adequate area of suitable land or on an ordinary percolating filter. Table XXXI. shows the amounts of these precipitants required, and Table XXXIV. the effects of their use. In the samples there dealt with there were still large amounts of grease present, and this entailed the use of corresponding amounts of precipitants, much greater than would be necessary in dealing with the seak effluent from a well-managed plant. The precipitation produces a considerable quantity of flocculent solids which even after twenty-four hours' sedimentation form 16 to 24 per cent. of the volume of liquid treated; but these amounts too would be greatly reduced if the grease were thoroughly removed previous to precipitation. Even after this reduction, however, it is probable that 1000 gallons would yield something like half a ton of liquid sludge containing 90 per cent. moisture. This sludge is very retentive of moisture, and would have to be dealt with in filter presses or dried by some analogous method, or it might be found possible to mix it with the acid sludge from the seak tanks and thus to recover the grease it contains. It might be economical to pump the precipitated liquid, without previous settlement, directly into filter presses, and thus avoid the expense of settling tanks and the cost of working them.

In the filtration experiments a small percolating filter was arranged in a glass cylinder, 4⅜ inches in diameter and 10 inches deep, filled with clinker taken from a bed which had been for some years in regular use at sewage works. The filtering material consisted of pieces about an inch in size in the lower layers, diminishing to about ¼ inch towards the surface. The top 2 inches consisted of a layer of fine material of which the particles were between ⅛ and $\frac{1}{10}$ of an inch. This top layer was employed with a view to ensuring proper distribution. Doses of 10 c.c. to 30 c.c. were applied at intervals, and the layer of fine material acted like a sponge, absorbing each dose for the time being and allowing the liquid to escape gradually into the body of the filter. The filter, after being gradually accustomed to treat this refuse, was used regularly for a month with doses at the rate of 36 gallons per cubic yard per day, but this quantity was applied in eight hours, and the filter was rested sixteen hours. The filtrate was collected and passed through another similarly constructed filter.

Table XXXIV. shows the results obtained by this method of treatment. The filter effluents were all incubated for fourteen days at a temperature of 37° C., but during this period did not show any signs of putrefaction. On examining the analyses it will be seen that the oxygen-absorbed and organic nitrogen figures are very greatly reduced by the filtration, and that large amounts of nitrates have been formed, in spite of the contention of Messrs Clark & Adams in their paper quoted on p. 65. It will be noted also that considerable amounts of suspended matter were found in

TABLE XXXIV.

TREATMENT OF REFUSE FROM GREASE RECOVERY.

(*Results expressed in parts per 100,000.*)

Average of	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Chlorides (as NaCl).	Nitrogen.				Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Hardness (in terms of CaCO$_3$).			Fatty Matter.
		Total.	Ash.	Total.	Ash.		Ammoniacal.	Organic (Kjeldahl).	Nitrous.	Nitric.	Total.	After Removal of Suspended Matter.	Total.	Permt.	Tempy.	
Four samples of supernatant liquid after precipitation of grease plant effluent	1390·2	10·2	2·2	1380·0	1013·0	45·2	7·28	12·72	nil	nil	67·42	...	572·8	425 0	147·8	9·85
Three samples of effluent from first experimental filter	1199·7	6·1	1·5	1193·6	1003·3	64·0	2·67	3·69	0·12	3·43	17·02	16·64	407·0	407·0	0·0	1·60
Three samples of effluent from second experimental filter	1167·1	6·3	2·9	1160·8	999·1	47·0	0·55	2·00	trace	5·46	11·37	11·41	454·6	371·5	83·1	trace

the effluents, but that the effect of these in raising the oxygen-absorbed figures was very slight. They could be removed by suitable humus tanks or straining filters (see p. 268).

The cost of this method of treatment is considerable. The cost of the grease recovery process may be calculated from the instance given on p. 114, and, as stated there, is more than covered by the return from the sale of grease. From the further process of treatment there is no such return. In the case of a mill from which 200,000 gallons of wool-washing refuse are discharged weekly, the following works would be required for the treatment of the effluent from the grease plant:—Four precipitation tanks, each of 10,000 gallons capacity, which might be made of wood, and with foundations, valves, and fittings, could be constructed for £400. A percolating filter 600 square yards in area, 6 feet deep, which, with foundations and fittings, would cost, say, £500 to £600. A second filtration might not be necessary, but it would be advisable to have a final settling tank of 4000 gallons capacity, the cost of which would be small. If it were found impracticable to press the sludge along with the magma or sludge from the seak tanks, a sludge-pressing plant to deal with 20 tons of wet sludge per day would be required, and this would cost altogether some £450. The whole outlay would thus be approximately £1400.

The working cost, taking precipitants at 6d. per 1000 gallons, would be £260 a year for chemicals; for sludge pressing, including the power, lime, cloths, labour, and repairs, at the rate of 2s. per ton of press-cake, which is more than the rate per ton at the Leeds Sewage Works (see City of Leeds Sewerage Committee, Annual Report, 1911), the cost would be £130 a year; and there would be over 1000 tons of pressed cake per annum to be disposed of, but this should have a sale for the extraction of the residual grease by means of a solvent, or for use as a manure. Very little labour would be required except in dealing with the sludge. The total outlay for the treatment of the effluent from the grease plant would therefore be something like £1400, which at 10 per cent. for interest and depreciation would amount to £140 per annum, while the cost of chemicals, sludge pressing, etc., would be about £390 per annum, making a total annual cost of £530. This would make the total cost of treatment, including everything except the price of the site required, 12d. per 1000 gallons, of which 9d. would represent the working cost. Against this must be placed the profit from the previous process of grease recovery and the value of the sludge cake.

In place of the method suggested above for the recovery of grease by acidification and further precipitation of the resulting effluent, it is possible to have only one precipitation process by using an iron salt to bring down together both the grease and the organic matters in the refuse. The resulting sludge can be afterwards acidified to release the fatty matters, when pressing with heat will yield liquid grease and a solution of the iron salts, and these, containing about 70 per cent. of the quantity originally added, can be used again for precipitation. Such a process has in fact been in use for some time at Messrs Kelsall & Kemp's mills at Norden near Rochdale for dealing with piece scouring refuse (see Tatton, *Proc. Inst. Civil Eng.*, 1900, vol. 140, p. 4). It does away with the need of settling tanks for precipitation of the grease plant effluent.

The Royal Commission of 1868 (Third Report, p. 29) suggested that such liquids as wool suds might be evaporated without undue cost, and an evaporation process which has been patented by Mr Walter Leach and Messrs John Smith & Sons, of Bradford, is probably the most perfect method of dealing with these liquids. The apparatus employed consists of a Yaryan evaporator, a centrifugal separator, and a cylindrical revolving incinerator. The wool suds are taken fresh as they are discharged from the washing bowls and passed through settling tanks to get rid of the bulk of the sand and mud. These tanks are three in number and have a total capacity equal to one and a half days' flow of the suds, and two are in use at one time, the third being out of use for cleansing purposes. The suds after this removal of sand are treated in a patent Yaryan evaporator, made by the Mirrlees, Watson & Yaryan Company, Ltd., Scotland Street Ironworks, Glasgow. This has been used very extensively for the concentration of dilute liquids, for instance, in sugar refining and in the manufacture of wood extracts; it has also been used for the distillation of water, as, for instance, at the port of Aden, where drinking water is distilled from sea water; and the plant serves both these purposes in the process of Messrs Smith & Leach. The evaporator itself is described in Chapter XI.

The suds are thus concentrated to $\frac{1}{10}$ or $\frac{1}{15}$ of their original bulk, while 80 per cent. of the evaporated water is recovered, both liquids issuing from the apparatus at a temperature of some 46° C. to 49° C. In the crude untreated suds the grease exists in the form of an emulsion from which it cannot be separated by centrifugal action, but by this concentration the specific gravity of the watery part is increased to such an extent as to make separation possible. The concentrated liquid, therefore, after being heated again to nearly boiling point, is further treated in a centrifugal separator, somewhat on the lines of a cream separator, where the rapid motion separates it into an outer layer of sand and mud, a middle layer of soapy watery liquid containing all the potash of the wool and an inner layer consisting almost entirely of wool grease.

The sand and mud adhere to the separator and are removed from time to time by hand as refuse, and by an ingenious contrivance the soapy potash liquor and the wool grease are caught up separately and conveyed to separate receptacles. The wool grease is purified by warming it up with water and allowing it to separate out again by cooling. The soapy potash liquor is further condensed in the Yaryan evaporator till it loses three-quarters of its bulk, when it is passed through a revolving cylindrical incinerator, such as is shown in Fig. 66 on p. 282, in which it is burned to get rid of the water and organic matter, and from which it issues as crude carbonate of potash.

The suds are thus totally got rid of, and in their place there remain—

1. Distilled water;
2. Wool grease;
3. Crude carbonate of potash; and
4. The sand and mud.

The distilled water is not perfectly pure, but contains a minute percentage of ammonia and a trace of grease, which have come over in the process of evaporation, but it is very valuable for use in the washing bowls. As much as 15 to 30 per cent. less soap is required when it is used instead of town's water, and it is recovered at the temperature required for wool washing.

The wool grease is much more valuable than the ordinary black grease recovered by the usual sulphuric-acid process, inasmuch as it is recovered from the fresh suds before they have undergone decomposition, and is quite free from mineral acid, none having been used in the process. It is free, moreover, from fatty acids, and can thus be used without further purification as a lubricant or for any of the other purposes for which the black grease, when purified, is used. As a matter of fact the price obtained for it has been nearly double the market price of black grease, and it has been found very useful as a lubricant in presence of water and at temperatures up to 38° C.

The carbonate of potash contains from 50 to 70 per cent. of pure carbonate, depending upon the mud and sand present, and can either be used in its crude state for washing other wool, or can be sold for purification.

The sand and mud possess little manurial value, but could be used with advantage on some soils for agricultural purposes.

There are two important incidental advantages in this process of dealing with wool suds. The suds are dealt with in a fresh state so that the whole process can easily be carried on without causing any nuisance, such as frequently arises from the careless management of ordinary soak tanks, and the whole apparatus occupies comparatively little room.

From the foregoing brief description it will be gathered that the method is one that, for the treatment of wool suds, does away with the necessity of discharging any liquid either into the streams or into the sewers, and yields several valuable bye-products, and the chief point to be inquired into is whether it can be carried out at a reasonable cost. The results of investigation upon this head are very satisfactory when greasy wools are being dealt with.

At Field Head Mills, Bradford, a plant dealing with the suds there produced was worked for several years, but was abandoned owing to changes in the class of wool washed.

The suds came from two sets of wash bowls, each set discharging 600 gallons an hour for ten hours a day, giving a total of 1200 gallons an hour or 12,000 gallons a day. The apparatus, including the Yaryan evaporator, two centrifugal separators, the incinerator, the boiler and furnace, and the necessary tanks and pumps, was, however, capable of dealing with double this amount. The space required for the whole apparatus, exclusive of the boiler and furnace and the set of preliminary settling tanks, was 48 feet by 24 feet floor space, by 40 feet in height, but the height could be reduced were more floor space available.

The cost of the plant was somewhat large, amounting to £4500 in all, including a special boiler, and the working cost was considerable both in coals and labour, as two men were required to attend to the apparatus and another man to act as fireman in the boiler house, where there was a special boiler, and the coals consumed in the boiler furnace and in the incinerator amounted to about 20 tons per week. On the other hand, the value of the bye-products recovered was very great. In June 1909 Mr Walter Leach furnished the Royal Commission on Sewage Disposal (Seventh Report, vol. 3, p. 102) with the statement given in Table XXXV., showing the results of a test of this apparatus and the capabilities of the plant.

In view of the great initial cost of the apparatus, it would be advisable in many cases that neighbouring manufacturers should combine in the erection of a central plant, to which their wool suds could be piped. A short consideration will show that the application of this method must be greatly restricted by the cost, and that, in fact, the process is only applicable in cases where valuable bye-products can be recovered. The Yaryan evaporator requires 1 lb. of coal for every 40 lbs. of water evaporated, including the 8 lbs. evaporated in the boiler. This, with coal at 10s. a ton, works out to 13½d. for coal alone for every 1000 gallons evaporated. In fact, the Yaryan Company only claim to produce distilled water at 2s. per 1000 gallons, taking into account the cost of the apparatus and the labour, as well as the coal used.

The process does not seem applicable, therefore, to the treatment of suds from the washing of previously scoured or skin wools or of mohair or alpaca, seeing that in these there are neither wool grease nor potash in quantities worth recovering. Unfortunately for the general adoption of this process, wool is combed on commission in most of the large woolcombing establishments—that is, it is sent in by manufacturers to be prepared for their use, and the different kinds of wool are mixed before being combed, so that it is difficult to know beforehand how much grease and potash will be recoverable. The samples given, however, in Table XXXI., taken from three different works, show that, generally speaking, there is quite sufficient of these bye-products present to make the process profitable.

A new process for the recovery of grease and potash from wool suds

TABLE XXXV.

TEST OF THE SMITH-LEACH PROCESS FOR TREATING WOOLCOMBERS' SUDS AT FIELDHEAD MILLS, BRADFORD. TREATING EFFLUENT FROM PURE AUSTRALIAN GREASY WOOL ONLY.

Quantity of suds treated per week, 55,000 gallons.

Actual running time of Yaryan Evaporator, forty-six hours.

	£	s.	d.	£	s.	d.
2 tons of pure wool fat, at £15 per ton .	30	0	0			
1 ton of carbonate of potash, at £15 per ton	15	0	0			
44,250 gallons distilled water, at 6d. per 1000	1	2	0			
Actual soap saved by using above water .	2	2	0	48	4	0
Coal used	£10	1	3			
Wages paid	3	8	3			
Interest and depreciation	12	0	0	25	9	6
Balance				£22	14	6

Capabilities of the Plant.

Quantity of suds. 110,000 gallons per week.

Actual running time of Yaryan Evaporator, ninety-two hours.

	£	s.	d.	£	s.	d.
4 tons of pure wool fat, at £15 per ton .	60	0	0			
2 tons of carbonate of potash, at £15 per ton	30	0	0			
88,500 gallons of pure distilled water, at 6d.	2	4	0			
Actual soap saved by using the above water	4	4	0	96	8	0
Coal used	£15	0	0			
Wages paid	5	8	0			
Interest and depreciation	15	0	0	35	8	0
Balance				£61	0	0

Note.—All grease sold up to to-day has been at £20 per ton. If the plant were running continuously night and day the profits would be proportionately larger.

has recently been patented (No. 7214, 1912) by Messrs Chambers & Hammond, and works on this system have recently been constructed. The largest item of expenditure in the ordinary acid method is the cost of the sulphuric acid necessary, and these gentlemen have discovered that by passing flue gases from the mill chimney through the wool suds the carbonic acid present is sufficiently powerful to crack the suds and separate the fatty acids. These can be removed by settlement of the liquid, leaving an aqueous solution of potassium carbonate, which, as already suggested, can be recovered by evaporation and incineration. The flue gases contain some sulphuric and sulphurous acids in addition to the carbonic acid, and these stronger acids must be removed by a scrubbing process if it is intended to recover potash from the suds.

The extraction of the grease from the raw wool by means of solvents has often been advocated, but has not yet come much into use. At Arlington Mills, in Lawrence, Massachusetts, and at the wool-combing establishment of Le Solvent Belge (Société Anonyme) in Verviers, Belgium, the wool in its raw state is treated in an iron receptacle with cold petroleum benzine. This dissolves out the grease, and, after being repeatedly used, is run off to be distilled for the separation of the benzine and the grease. The benzine remaining in the wool is driven out by a stream of warm carbon dioxide, and is also recovered by condensation, the carbon dioxide being returned for re-use.

At Fieldhead Mills, Bradford, a similar process, but in a different form of apparatus, was for a time adopted by Messrs John Smith & Sons, Ltd. The plant was somewhat costly and its use was not free from danger of explosion; it has, in fact, been thrown out of use probably for these two reasons. The loss of the solvent was said to be about 1 gallon per 100 lbs. of wool treated.

Another solvent process, in which bisulphide of carbon was used, was employed for some time by Messrs Isaac Holden & Sons at their Alston Works, Bradford, but after two accidents was abandoned on account of the danger.

A new apparatus for degreasing wool, by means of which the potash can also be recovered, bids fair to revolutionise the wool-washing process. This is the degreasing plant of Smith's Patent Vacuum Machine Co., Ltd., Dewsbury, which is shown in Figs. 17A and 17B.

The grease is first dissolved out of the wool by means of petroleum naphtha under diminished pressure, the naphtha being recovered by distillation, and the potash is afterwards extracted in the same machine by means of water, the aqueous solution being concentrated and incinerated. The grease and potash having thus been extracted from the wool, the completion of the cleansing operation is quite easy, and yields only a small amount of refuse.

The machine is very similar to one of the ordinary centrifugal driers found so commonly in woollen mills, but the central axis is set horizontally

Fig. 17a.—Smith's Patent Vacuum Degreasing Machine.

instead of vertically. There is an inner perforated basket divided by radial partitions into four compartments, into which the raw wool is fed. This is enclosed in an air-tight casing, in which a vacuum can be produced. The charge of wool having been introduced into the machine, a vacuum is produced by means of the vacuum pump shown in Fig. 17A. A sufficient amount of naphtha is introduced from an overhead storage tank, and by suitable gearing the central basket is made to revolve slowly, first in one direction and then in the other, dipping at each revolution into the naphtha at the bottom of the machine. The naphtha is thus made to permeate the wool thoroughly, and in a few minutes dissolves out the whole of the grease When this is accomplished the naphtha is run off into a greasy spirit tank. By a clever arrangement of the gearing a much more rapid motion (500–600 revolutions per minute) is then given to the central basket, so that by centrifugal force most of the remainder of the naphtha is driven out of the wool, leaving behind an amount equal to some 5 per cent. of the weight of the charge of wool. Provision is made for driving off even this remaining naphtha by means of a current of warm air or other suitable gas, and recovering it by condensation.

For the recovery of the potash a vacuum is again produced in the machine, a sufficient amount of water is introduced, and the operation is repeated as before, yielding a strong solution of potash, which is let off into a potash liquor tank. After this extraction of the potash the wool is dried by the centrifugal motion, and, if necessary, by the introduction of a current of warm air, and is then removed from the machine.

In the degreasing part of the process the naphtha, which is drawn from the apparatus by the vacuum pump, is passed through a cooler and vapour absorber, where most of it condenses, and is returned for re-use. The greasy spirit is drawn by the vacuum pump into a still, where the naphtha is evaporated under diminished pressure, to be also caught by a condenser and returned for re-use, while the grease remaining after the evaporation is run off into suitable storage tanks.

Since no water is used in the degreasing process, and the water used in the potash recovery must be wholly evaporated, there is no liquid refuse, except the distillate from the evaporation process, to be dealt with. By passing the wool through this apparatus it is freed from grease and from potash, and, incidentally, from sand and other impurities which have been set free by the extraction of the grease and carried away by the naphtha and the water. To cleanse it completely, therefore, it is only necessary to rinse it in a small quantity of water, yielding a refuse of slight impurity compared to ordinary wool-washing suds, and easily purified or otherwise disposed of.

The plant shown in Fig. 17B is capable of dealing with 700 to 1500 lbs. of wool at each charge. The loss of spirit amounts to about 5 per cent. of the weight of wool treated, and this loss can be further reduced by the warm air treatment.

On the other hand, the advantages claimed for the process are many, irrespective of the avoidance of the grossly polluting discharge from the ordinary wool-washing process.

1. All the grease and all the potash are recovered.
2. The material is left in a better condition than when washed in the ordinary way, no alkalies having been used.
3. There is no waste of wool fibre.
4. The operation being conducted under diminished pressure, the risk of explosion is reduced to a minimum.

It has usually been objected to the use of a solvent for degreasing wool that too much grease is extracted, leaving the wool in a dry, harsh condition, so that it "flies" when passing through the carding machines. In this apparatus, however, by mixing greasy naphtha with the pure spirit used any desired percentage of grease can be left in the wool.

Unlike the Smith-Leach process, this newer method is not only applicable to the cleansing of greasy wools, but can be used for others as well, although not then so profitably. It can also be used for removing the grease from yarns and pieces, or for dry-cleaning garments, for which purpose indeed it was originally invented. There seems no reason why it should not be slightly modified, and used for extracting the grease from magma cake, cotton waste, and bones.

Greasy wools, after treatment by any solvent process, still contain many impurities, consisting largely of valuable potash salts. These can be all washed out by water without the use of soap, and from this water the potash salts can be easily recovered as described on the preceding page.

It may be concluded from the above that if the ordinary method of cleansing wool is adhered to, the resulting suds can be purified partly by chemical and partly by biological methods so as to produce an effluent fit to be discharged to a stream, while the recovered grease and potash will go far towards paying for the cost incurred. On the other hand, methods of cleansing wool are available from which there need be very little discharge of liquid refuse, and that little of a nature which renders it easy to purify.

Silk Boiling.—Raw silk, as it is received by the manufacturer, is yellowish-grey or dull white in colour and rough to the touch, very different to the smooth and lustrous manufactured article. This is due in great part to the sericine or silk gum with which the fibres are coated as they leave the silkworm. Much of the silk reaches this country in hanks which have been reeled from the cocoons, but there is also a large amount in the form of compressed bales of waste silk, and of cocoons, more or less damaged in the reeling and still for the most part containing the dead silkworm. These cocoons are carded and spun very much in the same way as wool, and to facilitate these operations the sericine and other impurities must be removed from the fibre. When the silk is to be dyed the sericine must be partially or wholly removed from it whether it is in hanks or in cocoons.

The treatment adopted for removing these impurities is to boil the silk in a soap solution. This process is repeated once or twice with fresh soap solutions, and finally the material is boiled in a weaker solution, rinsed in tepid water, rendered slightly alkaline by the addition of sodium carbonate, in order to prevent the precipitation of lime soap on the fibre, and washed off in cold water. Usually the soapy water which comes from these final processes is used to make up the first tub.

The whole of the refuse discharged from a silk mill is therefore from the silk boiling, and a very foul liquid it is, even more polluting than wool-washing suds. It is a thick, brown, soapy liquid, often almost of a jelly-like consistence, and shaking produces in it a marked satiny appearance. It contains the soap which has been used in boiling, the sericine and colouring matter which have been extracted from the raw silk, and, where the cocoons have been boiled, many of the chrysalides and much organic matter which has been boiled out of them. It has a peculiar offensive odour even when fresh, and soon becomes putrid, when it has the very offensive smell of rotten pig manure.

In boiling silk waste about 220 gallons of water and 25 to 35 lbs. of soap are used for every 100 lbs. of silk, and occasionally a little soda is also used, and these, with the substances extracted from the silk, produce a liquid which is vastly more polluting than any ordinary domestic sewage (see Table XXXVI.).

The treatment of a liquid of this kind is quite a simple matter, although not inexpensive. By the use of a precipitant such as alumino-ferric or ferric chloride, and by settlement of the precipitated solids in tanks, a tank effluent can be obtained practically free from soap and sericine, and in a condition suitable for purification on land, or on a biological filter such as is described in Chapter XI. (p. 269).

In Table XXXVI. are set out the results of treatment by precipitation in settling tanks, followed by passing the tank effluent through simple straining filters. In this method of treatment a considerable difficulty arises in dealing with the sludge produced; the sericine, like the wool fat in wool suds, forms an emulsion with the water, and the sludge is somewhat difficult to dry. If acidified and pressed with the aid of heat, it does not yield up its grease readily, so that it is doubtful whether it would be an economical process to attempt the extraction of the grease. By running the sludge, however, on to an adequate area of such sludge filters as are described on p. 264, it can be sufficiently dried to be easily removed by spade and carted away. The dried sludge mixed with farmyard manure is very useful for agricultural purposes.

As the refuse is highly concentrated by the re-use of the weaker waters in the manner described, the amount of precipitant necessary is con-

TABLE XXXVI.

SILK-BOILING REFUSE.

(Results expressed in parts per 100,000.)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Total Fatty Matter (Ether Extract).
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Total.	By Filtrate.	
Crude	594·4	227·0	9·8	367·4	57·0	28·60	33·4	64·9	68·2	38·5	...
Crude	724·8	275·0	23·2	449·8	69·2	39·20	39·0	75·3	79·0	41·2	...
Crude	1646·8	366·0	86·0	1280·8	228·8	3·05	...	112·5	133·8	...	571·2
Crude	1130·3	351·5	28·0	778·8	85·4	4·90	44·2	95·2	150·6	115·7	...
Precipitated and filtered	717·4	45·6	6·7	671·8	190·0	17·24	30·4	48·2	37·2	33·4	...
Yarn washing	223·9	66·3	6·0	157·6	85·6	0·24	3·4	7·2	10·7	8·0	61·3

siderable. In some experiments it was found that from 300 to 500 parts of alumino-ferric or ferric sulphate were necessary to precipitate 100,000 parts of the refuse, and that after separation of the resulting sludge the liquid had an oxygen-absorbed figure equal to 40 per cent. of that in the original liquid. On applying the precipitated and settled liquid to a small percolating filter, such as has been described on p. 117, at the rate of 27 gallons per cube yard per day, during eight hours each day, a further purification of 80 per cent., judged on the oxygen-absorbed figure of the liquid applied to the filter, could be effected, making a total purification of 92 per cent.

Mr R. W. Oddy, F.I.C., of Rochdale, has treated this class of refuse by passing chlorine through it. This partially oxidised the refuse, with the formation of hydrochloric acid, which combined with the soda of the soap present and separated the fats. These were filtered off and boiled up with soda or potash into soap for re-use in the mill. The liquid, after the separation of the fats, was further purified by filtration.

This refuse is not in all cases to be regarded as a waste material, for in a silk mill to which a dyehouse is attached it is generally used up by adding it to the dye baths with the object of causing the colours to dye level. In one case in the West Riding of Yorkshire, where silks are dyed and silk-boiling refuse is used in this manner, the sludge recovered from the dyewaters is pressed in a sludge filter press by the aid of heat (see p. 116), and the grease thus recovered is made into soap which is used on the premises.

For Bibliography see end of Chapter IX.

CHAPTER VIII.

THE TEXTILE TRADES—*continued.*

Dyeing—Changed methods during last fifty years—Examples of purification works—Settling tanks—Waite's apparatus—Mackey's apparatus—Bell's patent filters—Watson's plant—Archbutt-Deeley system—Indigo dyeing—Sulphide black dyeing—Summary—Printing—Stiffening and loading—Carbonising and stripping—Mercerising.

Dyeing.—This process, although applied to almost all kinds of textile materials in every stage of their manufacture, yields refuse which does not vary greatly with the nature of the material, and which is therefore in all cases amenable to similar methods of purification. The methods of dyeing in use are almost innumerable and are constantly changing; they have, in fact, been revolutionised since they were reported upon by the Royal Commissions of 1865 and 1868 (see 1865 Commission, Third Report, p. 22; 1868 Commission, Third Report, p. 18).

At that time the dyeing materials chiefly in use were different kinds of woods, which were for the most part extracted in the dye baths themselves. As mordants for fixing these dyes, ferrous sulphate, alum, argol, and bichromate of potash were generally used, and were added to the dye liquor in the vat, where they precipitated the colouring matter within the fibres of the material being dyed. This process was an extremely wasteful one, for much of the colouring matter was precipitated in the liquid contents of the vat, where it had little effect upon the fibre, and was afterwards discharged as refuse. It also gave rise to gross abuse of the streams, for both Commissions repeatedly referred to the large quantities of spent woods discharged to the streams and to the pollution of the water and obstruction of the flow thus caused. The effect produced on the rivers of the West Riding of Yorkshire they summed up by stating that with very few exceptions these streams ran with a liquid which had more the appearance of ink than of water. The 1865 Commission, in their Third Report (p. 24), stated that very few attempts had been made to cleanse dyewater.

At the present day the use of woods as a source of colouring matter is rapidly decreasing. Where they are still used the colouring matter is usually extracted from them by a special manufacturer, who sells the extract to the dyer, and who can easily provide himself with facilities for burning or otherwise getting rid of the spent woods. In many cases these are dried in a centrifugal machine, mixed with fuel, and burnt in the boiler furnaces. But for the most part modern colouring matters consist of derivatives of coal tar, obtained by processes based upon the discoveries of Perkin in the middle of last century. These dyes are extremely soluble and highly concentrated, so that the dyer now buys them by the pound, whereas he formerly bought dyewoods by the ton. They are, moreover, free from impurities, so that when a dye vat is partially exhausted of colouring matter it need not be discharged, but can be made up afresh by the addition of further quantities of dye. Improved machinery has also greatly lessened the polluting discharges and the waste of colouring matter. In such machines as those of Obermaier and Dreze the contents of the dye vat are circulated repeatedly through the materials being dyed, until nearly the whole of the colouring matter is exhausted, and the volume of dye liquor used in these machines may only amount to one-tenth of that required in an ordinary dye vat. The exhaustion of the colouring matter is also sometimes achieved by extracting it with a new batch of goods, which is afterwards finished off in a freshly made up vat.

Notwithstanding all these improvements the discharges from every dyehouse are still at times of a polluting character. When it is necessary to change to another colour a fresh vat must be prepared, and the contents of that in use are usually discharged; mordanting materials are also still used, and the vats in which they are contained are let off from time to time; the old process of dyeing with wood or extracts with the aid of an iron mordant is still employed, especially for cotton goods and in "burl dyeing" or the colouring of vegetable fibres in woollen goods; the coolings and rinsings of the goods as they are withdrawn from the vats often contain considerable amounts of suspended matter; while in all dyehouses some quantity of soapy liquid or of soap bark or fuller's earth is used at times for cleansing purposes; the various dye liquors, moreover, are often highly coloured and strongly acid, and practically always contain some fibres which have been washed off the goods. It will thus be seen that even in the case of the most modern dyehouses polluting discharges have to be dealt with, whilst there are still a considerable number of dyehouses, especially the smaller, where the old and more polluting processes of dyeing are still in use.

It would be difficult, and for the present purpose it is unnecessary, to explain in detail the various processes employed in a dyehouse. To describe the process generally, it may be said that the goods, which must previously have been cleansed, and especially freed from all greasy matter, are soaked or boiled in the dye vats, and often either before or after this are passed through a solution of mordant to fix the colouring matter. They are then usually thoroughly washed with large volumes of clean water to cool them after boiling, and to remove the excess of dye. In some cases this final cleansing is assisted by the use of soap, soap bark, or fuller's earth.

Although the refuse varies considerably in various places, it is always, as has been said, amenable to the same kind of treatment, that usually adopted taking the form of screening and settlement, with or without chemical precipitation, followed by filtration.

In many dyehouses, and especially in those dealing with heavy woollen goods, large amounts of loose fibre escape in the waste dyewaters, and it is important that before any attempt is made at further purification these should be thoroughly removed by screening apparatus, such as is described on p. 239. These fibres have a considerable market value, which in very many cases amply repays the cost of any screening apparatus. If they are not removed they add greatly to the amount of sludge which may be deposited in any settling tanks and in other ways increase the difficulties of purification, for example, by forming a felted coating on the surface of the filters.

The means adopted for the further treatment of waste dye liquids vary greatly in the methods of adding precipitant, the kind of settling tank employed, and in the form of filter used, and these variations can best be illustrated by describing a few works actually in use, and setting out the analyses of the various kinds of refuse and of the effluents produced.

Ordinary Settling Tanks.—As an example of the simplest form of settling tanks applied to the treatment of dyewaters those shown in Fig. 18 may be taken. They consist of a series of seven settling tanks, which were originally followed by two cinder filters, but, as it was found in practice that the tank effluent was little improved by passing through the filters, these were converted into two additional settling tanks, thus giving a total capacity of 56,000 gallons. The refuse here dealt with amounts to 40,000 gallons per day and comes from the dyeing and finishing of cotton cords, and usually contains suspended matters in amounts varying from 10 to 20 parts per 100,000. After simple settlement in the tanks, the suspended matters are so effectually removed that the effluents have never been found to contain more than 3 parts per 100,000. At somewhat varying intervals the tanks are run off to the sludge filter, where the water percolates away and the sludge is left to dry. Eight tons of air-dried sludge are removed from the works per annum.

The total cost of these works was £400, and the only working costs are those entailed by the cleansing of the tanks and the removal of the sludge, which together amount to £6 per annum.

Waite's Apparatus.—Since the need of an apparatus for the treatment of trade effluents on a limited site has made itself felt, not only have new forms of apparatus been devised, but various methods originally intended for the purification or softening of water have been brought into use. Such an apparatus, patented (No. 11,366, 1901) by Thomas Waite, 3 Hillside Road Works, Bradford, has been found very useful in purifying dyewaters in cases where the available site for purification works is limited in area. The following description, presented as a report to the

West Riding Rivers Board in 1908, gives full details of a plant of this kind erected at Wensleydale Mills, Batley, in 1904. The plant is no longer in operation there, where another class of trade is now carried on, but it has been purchased by another manufacturer and removed to his premises for the purification of the refuse from his dyehouse, the effluent being re-used as it was at Wensleydale Mills. Since the date of this report Mr Waite has erected several works of the same kind with equally successful results.

The accompanying diagram (Fig. 19) shows the principle of the working of the apparatus, although it does not represent the works actually erected at Wensleydale Mills. The apparatus as there shown consists of three vertical iron towers. The water to be purified is pumped up to the top of the towers on to a small water-wheel B, which drives a very simple apparatus G, for adding chemical precipitants in proper quantity, a stirring apparatus in the top of the first tower for mixing the chemicals with the water, and gearing HK for automatically discharging sludge from the towers. The water after the addition of the precipitants passes down the first tower and out by a side opening one or two feet from the bottom into the second tower near the bottom; in this tower it rises to the top, depositing suspended solids as it rises, and passing through a filter of wood shavings at the top of the tower. The water is allowed to overflow from the top of the second tower down a pipe which delivers it into the third tower near the bottom, from which point it rises through the third tower and again is filtered through a layer of wood shavings. The overflow from the top of the third tower is conveyed away by a channel to a storage cistern from which it is delivered for use.

So far then the process is one of the precipitation of the impurities by chemicals and their separation from the liquid during an upward flow, a separation which is assisted to some extent by the filtration through wood shavings. The advantages of such a form of apparatus are that, including the height of the three towers, a great depth of settling tank is provided, and during the progress of the water through the second and third towers the rate of flow is very greatly reduced, and these two features give the suspended solids ample opportunity of subsiding.

The other special features of the apparatus are the method of adding the precipitant and the method of getting rid of the sludge separated from the water. Sufficient precipitant in solution is added daily in tanks, D, E, F, at the top of the towers, to deal with the day's flow of water, and the tanks are three in number, so that three different precipitants in different proportions can be added. In the first tank milk of lime is placed, in the second alumino-ferric, and in the third carbonate of soda. The water-wheel B drives three subsidiary wheels G, G, G, which revolve in the tanks of precipitant. On the rims of these wheels little buckets are fixed, which as the wheels revolve draw up a certain quantity of the precipitant from each tank and empty it into a channel which carries it into the pipe conveying the water to the top of the first tower. Provision is made for adding the lime and mixing it with the water before the other precipitants are added. The speed at which these bucket-carrying wheels revolve depends upon the rate at which the water is pumped, and thus the quantity of precipitant added varies directly with the quantity of water passed through the apparatus.

The apparatus for discharging the sludge is equally automatic. At the bottom of each tower at K there is a valve governed by a long rod which is connected by gearing with the water-wheel at the top of the tower. By a simple contrivance these valves can be set to open at fixed intervals of a quarter of an hour, an hour, or longer, as may be required, the rate of opening being again dependent upon the rapidity with which the water is being passed through the plant. The valves when opened only discharge a few gallons of liquid sludge and then are automatically closed. The sludge is received on sludge filters, the water draining from which is run back into the pump well and again passed through the apparatus. The sludge from which the water has drained, when sufficiently dry, is removed by spading from the surface of the filters.

The apparatus is thus as nearly automatic as possible. The small tanks containing the precipitant are filled up daily, the pumps set at work, and as long as the gearing is in good condition the apparatus needs no further attention, beyond the periodical cleansing of the sludge filters.

The apparatus erected at Wensleydale Mills is almost exactly on these lines (see Figs. 20 and 21). It was intended to deal with 3000 gallons of refuse per hour, but has been at times dealing with about 50,000 gallons per day of ten hours. The average amount dealt with may be taken as about 30,000 gallons a day. The refuse runs into a sump well 23 feet by 13 feet by 15 feet deep, or 28,000 gallons in capacity. From this the refuse is pumped a height of 45 feet to the water-wheel at the top of the plant, from which it passes down the first or mixing tower, where it has the chemicals added to it. This tower is 30 feet in height and has a diameter of 3 feet and a capacity of some 1300 gallons. The liquid as it escapes from the bottom of the mixing tower is passed into the largest settling tower near the bottom. This tower is 30 feet in height and 8 feet in diameter, with a capacity of some 9400 gallons. The liquid rises through this tower and, overflowing at the top, is conducted by pipes into the bottoms of the remaining two towers, which are each 7 feet in diameter, 30 feet in height, and 7200 gallons in capacity. At the top of these final towers there is a layer of wood shavings through which the liquid is strained and the final effluent escapes. The total capacity of the four towers therefore is 25,000 gallons, and the rate of upward flow in the second or largest tower when 3000 gallons per hour are passing is about 2 inches per minute, while in the final towers it is about 1¼ inches per minute.

The sludge filters provided are six in number, each 9 feet by 8 feet.

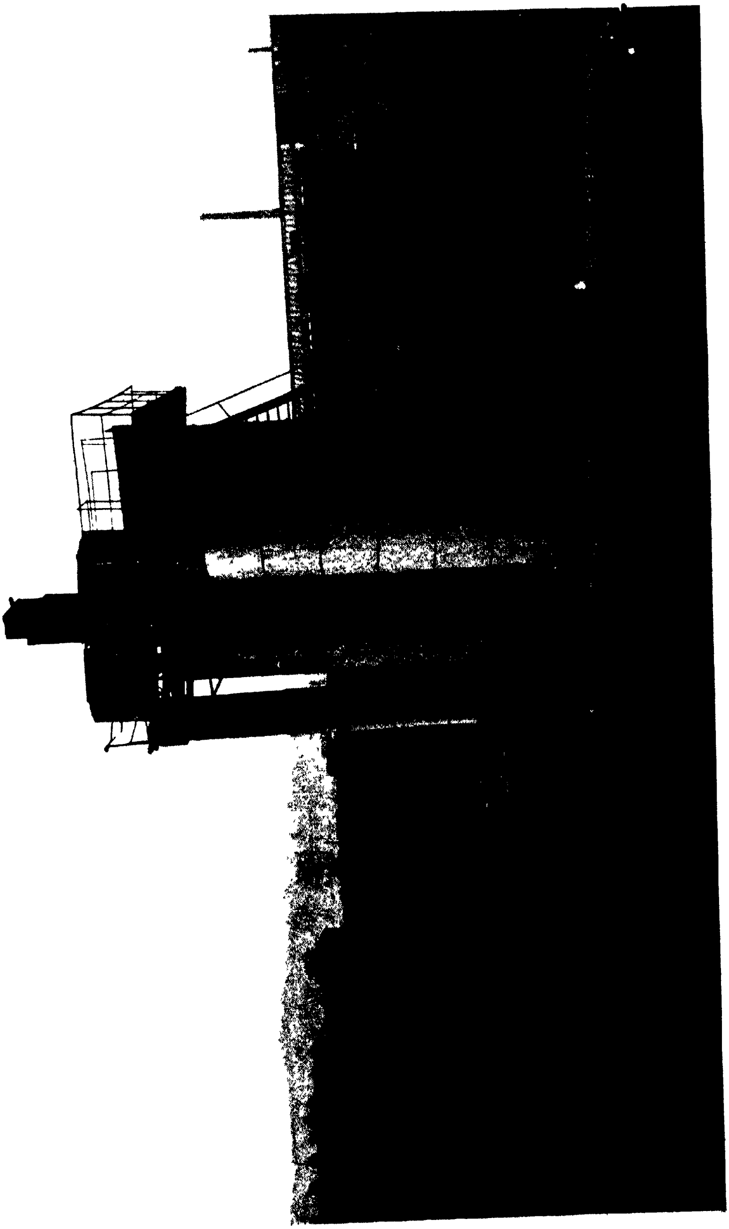


FIG. 21.—Waite's Apparatus.

They are composed of broken stone with furnace clinker on the surface, and are 15 inches in depth. They are protected from rain by a light roof. The effluent from the underdrains is received into the sump and circulates again with the refuse waters for treatment. The sludge is automatically discharged from the towers as described above, from the first tower at intervals of some three and a half minutes, and from the final towers every ten minutes. The quantity at each discharge is about 1 or 2 gallons, and the sludge contains a very great deal of moisture. (See analyses in Table XXXVIII.). Each sludge filter is used for about three days, when it contains some 12 inches of sludge. It takes usually about seven days, depending on the weather, for this sludge to dry sufficiently to be removed by spade, when it is thrown out on the ground alongside, allowed to dry there still further, and finally carted away to the cinder tip. The amount thus carted away is approximately 10 tons in a month.

The total area occupied by the plant is 165 square yards, including 57 square yards taken up by the filters. The refuse dealt with is from the scouring and dyeing of pieces. The thicker scouring refuse is not treated here but in a separate plant, and some of the washing-off waters after scouring are stored in the wash-house and re-used, so that only the final washing-off waters are received here. The dyeing processes in use are chiefly the dyeing of rags and pieces with ordinary acid dyes and direct cotton colours (diamine, etc.), and burl dyeing with extract of myrobalans and an iron salt. The quantity of refuse dealt with daily varies very greatly according to the trade being done. The maximum is stated to be about 50,000 gallons a day.

Samples were taken over considerable periods on three different days, so as to obtain an average of the refuse waters treated, and of the final effluent, and other samples of the final effluent and of the sludge, etc., have been taken at various times. Analyses of these are given in Tables XXXVII. and XXXVIII. Tests were made with colouring matter to ascertain the time taken in the passage of the refuse through the apparatus. Fluorescein was poured into the top of the mixing tower and after an hour and twenty minutes was found in the effluent. It was still, however, present in the effluent after the apparatus had been continuously working for ten hours.

At first the precipitants added were lime, alumino-ferric, and soda, but latterly only the two former, 80 lbs. of lime and 56 lbs. of alumino-ferric being the maximum amounts used per day. Taking the prices of these materials at £1, 2s. 6d. and £2, 17s. 6d. per ton respectively, and the amount of refuse treated at 50,000 gallons, the cost of these chemicals amounts to just over ½d. per 1000 gallons.

The only labour necessary to keep the plant working is attention to the pumping, the daily addition of the chemicals to the small tanks at the top of the main tower, and the removal of the sludge from the sludge

TABLE XXXVII.

SAMPLES TAKEN AT WENSLEYDALE MILLS (WAITE'S APPARATUS).

(Results expressed in parts per 100,000.)

Sample of	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.)		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Alkalinity (as Na_2CO_3).	Acidity (as H_2SO_4).	Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).				Total.	Permt.	Tempy.
Dyewaste (average of two samples) .	193·21	25·91	4·92	167·3	135·2	0·57	0·67	2·01	10·28	trace	...	15·2	9·6	5·6
Washing-off water .	140·80	88·80	20·20	52·0	32·2	trace	0·96	1·30	16·25	20·7	...	...	...	...
Crude refuse entering plant (average of three samples) .	251·86	26·96	5·37	224·9	192·3	0·63	0·58	0·97	10·83	nil	nil	63·0	40·4	22·6
Effluent from 8-foot tower . . .	267·48	7·68	2·52	238·8	202·8	0·81	0·39	0·97	5·30	nil	nil	102·0	59·0	43·0
Sludge filter effluent	343·16	20·16	11·88	323·0	267·2	1·20	0·53	1·11	5·57	trace	...	102·1	94·0	8·1
Final effluent (average of nine samples)	235·93	1·43	0·94	234·5	207·7	0·64	0·25	0·66	2·90	4·8	nil	62·1	59·9	2·2

filters to the tip. This latter work occupies a man with a horse and cart for six hours a month. The rest of the labour is estimated to take up less than half of one man's time.

The effluent from this apparatus has been constantly re-used in the mill for trade purposes. It is discharged into a large iron tank, where water from a well is mixed with it in the proportion of 1 to 4. From this tank water is drawn for use in the dyehouse, and the surplus is used for condensing and for flushing water-closets.

The company state that since the erection of Waite's apparatus the re-use of the effluent has been a material advantage. During the year ended 30th June 1908, 1,400,000 gallons of the effluent have been used in the dyehouse, instead of which town's water at a cost of 6d. per 1000 gallons, or £35, would have been necessary, and the dyer finds it excellent for his purposes. For condensing purposes also it was formerly necessary in times of drought to augment the supply from the stream with town's water, and at least 400,000 gallons of the effluent have been used for this purpose, resulting in an annual saving of £10. Besides the monetary gain, it has been found that having the supply from Waite's apparatus available has prevented the stoppage of the mill for short periods when the water of the stream has failed in times of drought. Four water-closets formerly flushed with water from the town's mains are now, moreover, flushed with the effluent from Waite's apparatus, and this also means a considerable reduction of the water bill.

TABLE XXXVIII.

SLUDGES TAKEN AT WENSLEYDALE MILLS (WAITE'S APPARATUS).

(*Results expressed in parts per cent.*)

Sample from	Moist Sludge.			Dry Solids *			
	Moisture	Organic and Volatile Matter.	Ash.	Organic and Volatile Matter.	Ash	Nitrogen (Kjeldahl).	Fat after Acidification.
Sludge filter . .	82·30	8·64	9·06	48·81	51·19	...	14·24
,, . .	80·51	12·02	7·47	61·67	38·33	...	26·63
,, . . .	93·51	2·56	3·93	39·45	60·55	0·83	
Towers . . .	99·32	0·19	0·49	27·94	72·06	0·96	..
8-ft. tower . . .	98·21	0·67	1·12	37·35	62·65	0·94	.
7-ft. tower (R) . .	98·57	0·46	0·97	31·94	68·06	0·83	.
7-ft. tower (L) . .	98·56	0·43	1·01	30·35	69·65	0·77	...

* The figures are calculated from an analysis of the moist sludge.

The cost of the plant is given by the company as follows:—

Capital cost of plant:

Sump well	£68	10	0
Waite's apparatus	530	0	0
Sludge filters and roof	88	0	0
Pump and steam pipes	62	0	0
Total	£748	10	0

Weekly cost of treatment:

One man 3 days per week at 25s.	£0	12	6
Chemicals at ½d. per 1000 gallons (180,000 gallons per week)	0	7	6
Man and horse and cart, 1½ hours per week	0	1	6
Steam, say (The Engineer says this is over-estimated.)	0	5	0
	£1	6	6

Repairs and Renewals: In the four years the plant has been running these have amounted to £20, chiefly due to repairs of the engine and pump, the latter of which was affected by the acid dyewaters

Allowing 10 per cent for interest and depreciation on the initial cost of the plant, the total cost of treatment, exclusive of the cost of the site, amounts in this case to 4d. per 1000 gallons.

This and the following method of purification are to be recommended more especially in the case of a smaller dyehouse, where the employment of a special manager of the purification works would be too great an expense. The attention required is inconsiderable, as it is only necessary to see that the pumps are in proper order, that the supply of precipitants is kept up, and that the sludge is removed with regularity.

Mackey's Apparatus.—Another form of plant for the purification of dyewaters (see Fig. 22) has been erected for Messrs Brigg & Sons, Dock Ing Mill, Batley, by W. McD. Mackey, F.I.C., who has taken out patents (Nos. 11,410, 1905, and 1327, 1911) for the apparatus. It somewhat resembles Waite's plant, but is quite distinct in its principle.

The dyewaters dealt with at Dock Ing Mill are from the dyeing of pieces, the dyestuffs used being chiefly anilines, acid and neutral, with ground myrobalans and an iron salt for the cotton or burl dyeing Bichromate of potash and sulphuric acid, and sometimes a patent bleaching agent, "hyraldite," are also used to discharge colours from some of the goods. Town's water is used in the various processes, and the total discharge of refuse is estimated at 30,000 gallons a day on an average.

The refuse is received in a sump on the dyehouse drain, about 20 feet by 3½ feet by 3 feet, or some 1300 gallons capacity. This is smaller than it ought to be to cope properly with sudden discharges of several cisterns in the dyehouse at once, but the space available is very limited. From the sump the refuse is lifted by a ram pump, capable of lifting 6000 gallons an hour, to an elevated mixing or averaging tank of wood, which has a capacity of 10,500 gallons, and is raised on brick piers 20 feet in height. The total lift is over 30 feet.

In a small wooden tank fixed at the head of the averaging tank lime is placed, and into this a proportion of the trade liquids is directed, and the contents are kept constantly agitated by paddles which are kept in motion by means of a small water-wheel driven by the bulk of the refuse. The quantity of lime required to precipitate the solids varies very considerably from day to day, for the refuse waters are sometimes strongly acid, and at other times neutral or even alkaline, but usually about 35 parts per 100,000 are necessary. The bulk of the refuse is delivered into the tank underneath the water level, being first joined by that portion which has been passed through the liming chamber. The contents of the tank are drawn off from the bottom at the end farthest from the inlet, and no attempt is made to retain the suspended solids, the purpose being to obtain a thorough mixture of the various kinds of refuse with one another, and with the lime which has been added.

The effluent from the mixing tank is conveyed by a 4-inch pipe to the lowest point of a sloping cylindrical tank, which is set underneath at an angle of 12° from the ground level. Provision is made for keeping the pressure on the liquid in the lower tank at a constant head. This tank is 28 feet in length and 7½ feet in diameter and has a capacity of 7700 gallons. The outlet is at the highest point, which is somewhat lower than the bottom of the mixing tank, so that the lower tank is kept continually full of the liquid, which is, while the apparatus is at work, constantly entering at the bottom, rising gradually, and escaping at the top. The idea of the patentee is that the rising liquid leaves behind it any suspended solids, which accumulate in the lower part of the tank, so as to form an obstacle in which further suspended solids in the incoming liquid are entangled and thus aided to deposit. The inlet pipe to the sloping tank is moreover directed upwards, and thus gives an eddying motion to the liquid, which probably aids materially in the deposition of solids. The sludge which accumulates in the lower part of the tank is let off from time to time by a sludge outlet, but care is taken to retain a certain amount to aid in the process as above described.

The tank effluent, thus freed from the greater part of its suspended solids, is further purified by filtration through coke. It is carried from the top of the tank in a 4-inch pipe to the bottom of a cylindrical filter, a break being provided to prevent siphonic action. The filter consists of a vertical cylinder, 6½ feet in diameter and 12 feet in height, and filled for 9 feet of its length with pieces of coke of sizes ranging from ½-inch to 1½-inch cubes. The bottom 1½ feet of the cylinder contains no coke, and into this the tank effluent is passed, and rises through the coke to escape from its upper surface into a compartment 1½ feet in depth, from which it is discharged as the final effluent. This is conveyed to the mill dam and used, mixed with stream water, for condensing. Any sludge which accumulates in the compartment below the coke is drawn off through a sludge valve about once a day, and when this is opened the reversal of the flow of liquid through the coke helps to wash out any solids which have become entangled among the particles.

The sludges from the tank and from the filter both contain a large proportion of water and are discharged to one of three sludge filters, each 8 feet by 12, formed of engine ashes 2 feet in depth and well underdrained, with outlet to the stream. The sludge, which is let off from the tank about once a week, even after lying on the sludge filters for a few days, still contains over 90 per cent. of water, and is shovelled out and allowed to lie on the ground to lose further moisture by evaporation. Of this air-dried sludge about 12 tons have been produced in four months' working.

The apparatus is specially designed to take up little space, and only occupies 120 square yards. The cost of a complete plant for dealing with 3000 gallons an hour Mr Mackey estimates at £350, and the proportionate cost of a larger plant would, of course, be somewhat less. The working cost is not very great. Taking the cost of the lime used as a precipitant in the proportion of 35 parts per 100,000, or 25 grains per gallon, with lime at £1, 2s. 6d. a ton, the cost of the lime used is under ½d. per 1000 gallons, or 1s. 1d. per day. There are also the cost of pumping, a little attention in adding the lime, and the removal of the sludge to be provided for, but, excluding the last item, Mr Mackey reckons that the plant requires about an hour a day of a man's time.

This plant at Dock Ing Mill has been constructed to suit the site, and a better arrangement might be devised in other circumstances. There seems to be no reason in ordinary cases for having the sump and the mixing tank separate, and the addition of the precipitant to the liquid before the latter is pumped would tend to produce a much better admixture. If this were done, the sloping tank could be placed over the collecting and mixing chamber, and thus room could be economised. In all cases, however, a small overhead tank must be provided to feed the main tank at a constant head.

The effluent from the sludge filters should be returned to the collecting chamber to be passed again through the apparatus. In such case the sludge filters could be made shallower, for the purity of the filter effluent would not matter, and thus the sludge could be dried off much more quickly.

Several series of samples have been taken and analyses made (see Tables XXXIX. and XL.). On one occasion some twenty pieces were dealt with in the dyehouse. In the case of six pieces the wool and cotton were dyed at the same time in a neutral bath, and in the case of the remaining

Table XXXIX.

SAMPLES TAKEN AT DOCKING MILL, BATLEY (MACKEY'S APPARATUS).

(Results expressed in parts per 100,000.)

Sample of	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Alkalinity (as CaO).	Acidity (as H_2SO_4).	Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).				Total.	Permanent.	Temporary.
Crude refuse (average of four samples) .	191·88	28·58	2·23	163·3	124·9	0·79	0·57	2·20	15·38	...	15·7	49·5	41·3	8·2
Precipitated refuse entering sloping tank (average of two samples) .	322·23	39·53	25·45	282·7	254·3	1·31	0·42	1·73	10·40	43·1	...	226·8	182·1	44·7
Effluent from sloping tank (average of two samples) .	267·13	2·73	2·36	264·4	231·6	0·47	0·26	0·69	5·23	24·3	.	210·6	136·9	73·7
Effluent from sludge filter . . .	240·64	13·44	3·60	227·2	194·4	0·78	0·12	0·46	4·56	trace	..	81·4	59·0	22·4
Final effluent (average of three samples) . .	139·09	0·99	0·54	138·1	116·9	.	...	.	3·17	8·4	..	54·8	44·5	10·3

fourteen the wool in the pieces was dyed in an acid bath, and the cotton dyed as a separate process, in eight pieces with extract of myrobalans and iron liquor, and in six in an alkaline aniline cotton dye bath. The mixed dyewaters were therefore of an acid character, and lime to the extent of 77 grains per gallon was used to precipitate.

On another occasion ten pieces were being dyed with direct aniline dyes and Glauber salts, and two were subsequently burl dyed; and four pieces were being stripped with acid. The amount of refuse discharged that morning was from 10,000 to 15,000 gallons, and 28 grains of lime per gallon, approximately, were being added to the dyewaters

The final effluent has generally been practically free from suspended solids, but still somewhat coloured, with a green or yellow shade. To test the time taken by the liquid to pass through the apparatus colouring matter was poured into the averaging tank along with the trade refuse being treated. The colour was seen in the effluent from this tank in twenty minutes; it appeared in the effluent from the sloping tank after another fifty minutes; and in the filter effluent after another thirty minutes: taking, therefore, a hundred minutes to pass through the whole apparatus.

TABLE XL.

SLUDGES TAKEN AT DOCK ING MILL, BATLEY (MACKEY'S APPARATUS).

(*Results expressed in parts per cent.*)

Sample of	Moist Sludge.			Dry Solids.*				
	Moisture.	Organic and Volatile Matter.	Ash.	Organic and Volatile Matter.	Ash.	Nitrogen (Kjeldahl).	Fat after Acidification.	Lime (CaO).
Sludge from tank .	98·65	0·48	0·87	35·19	64·81	0·91	...	18·80
Air-dried sludge .	91·26	4·34	4·40	49·65	50·35	1·83	3·77	...
Air-dried sludge .	84·25	4·36	11·39	27·67	72·33	1·22	2·16	26·00

* The figures are calculated from an analysis of the moist sludge.

Since this plant was constructed in 1908 Mr Mackey has erected a good many more on the same lines, but in these he has left out the coke strainer, as experience has shown that its effect is very slight. He has also adopted a much improved method of adding the precipitant, somewhat similar to that described on p. 133. Most of these new works deal with very much larger volumes of refuse, in one case, at Greetland Dyeworks, with 300,000 gallons per day, but the plant in such a case is simply a reduplication of several units like that described, except that there is only one mixing tank and one apparatus for adding precipitants.

Bell's Apparatus.—Bell's Patent Filter is another apparatus originally devised for the purification of water. It has been brought into use for the treatment of dyewaters, and erected by Messrs Bell Bros., Calder Ironworks, Ravensthorpe, for Messrs Edward Ripley & Son, Ltd. (Branch of the Bradford Dyers' Association, Ltd.), at Bowling Dyeworks, Bradford (see Fig. 23).

At these works the processes which give rise to polluting liquids are piece scouring and dyeing. Only pieces are dyed, and these are practically all woollen, or union goods in which the cotton warp has been previously dyed. Nearly all the dyes used are soluble acid colours.

The thicker piece-scouring suds are treated in a seak plant, the effluent from which is discharged to the public sewer. The final washing and cooling waters from the dyehouse are run into a storage tank, which also receives hard well water and purified refuse, and the contents of this tank are softened in a separate set of Bell's Filters and pumped up to the general reservoir for use in the dyeworks.

The washing-off waters after piece scouring and the rest of the dyewaters, amounting to 600,000 gallons per day, are run into a series of large dams, where some settlement takes place. From these dams the refuse is pumped into a settling chamber, and through this into four of Bell's Filters. The effluent from these is taken into the storage tank abovementioned, to be further purified for re-use, or is discharged either directly to the stream or to a large reservoir, from which it is drawn by various mills to be used as condensing water and returned again, but finally overflows to the stream.

The two sets of filters, for softening the cleaner water and for purifying the refuse, are identical in construction, and the only difference in working them is in the amount and nature of the chemicals used as precipitants.

The dams into which the refuse is discharged from the dyeworks are three in number, and have a total capacity of about 2,018,000 gallons. As these dams are seldom, if ever, cleaned out, practically the only results of their use are a mixture of the various discharges and some septic action, which must have the effect of somewhat altering the nature of the solids present. Owing to this septic action, and the fact that there is sulphuretted hydrogen in the well water used, almost all the samples taken, whether of crude or treated refuse, show the presence of sulphuretted hydrogen, and the gases escaping from the putrefying sludge in the dams can be set alight on the surface of the water.

The refuse is drawn from the dams at the rate of 30,000 gallons per hour throughout twenty hours of the day, through a 12-inch suction pipe, into which a solution of chemicals is pumped. The precipitants added are aluminium sulphate 4·46 parts per 100,000, lime 1·78 parts, and soda 0·67 parts, and these are previously dissolved in special tanks fitted with

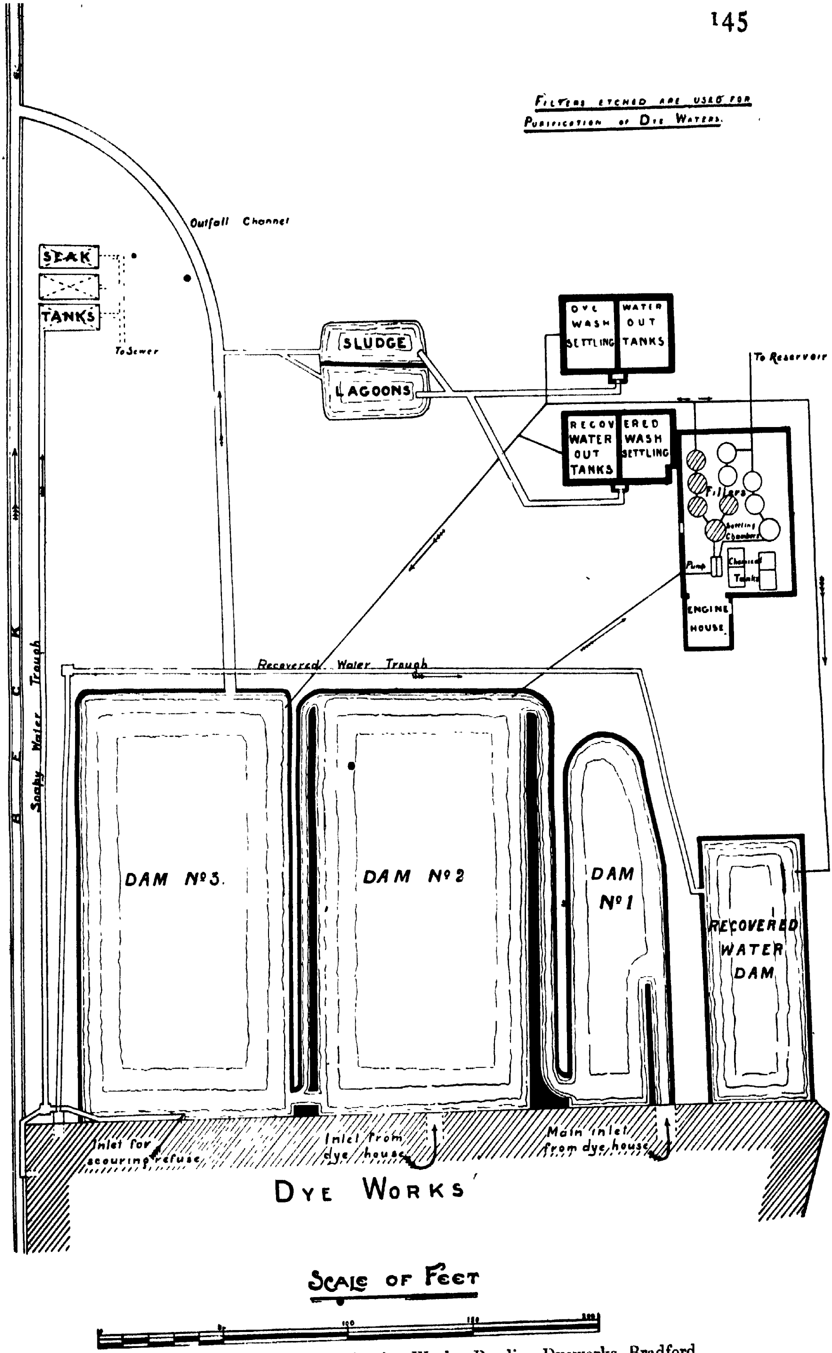


FIG. 23.—Plan of Purification Works, Bowling Dyeworks, Bradford.

agitators. They become thoroughly mixed with the refuse as it passes through the pump.

From the pumps the refuse passes into a closed cylindrical settling chamber of steel, 9 feet in diameter and 16 feet high, with a capacity of 6500 gallons. The delivery pipe passes inside the settling chamber at a point about 3 feet from the bottom, and the outlet from the chamber is at the highest point. The delivery pipe is branched, and the branches are perforated on the underside, and have plates fixed over them, with the object of ensuring an even upward flow over the whole sectional area of the chamber. If this were attained the upward velocity would be about 1¼ feet per minute.

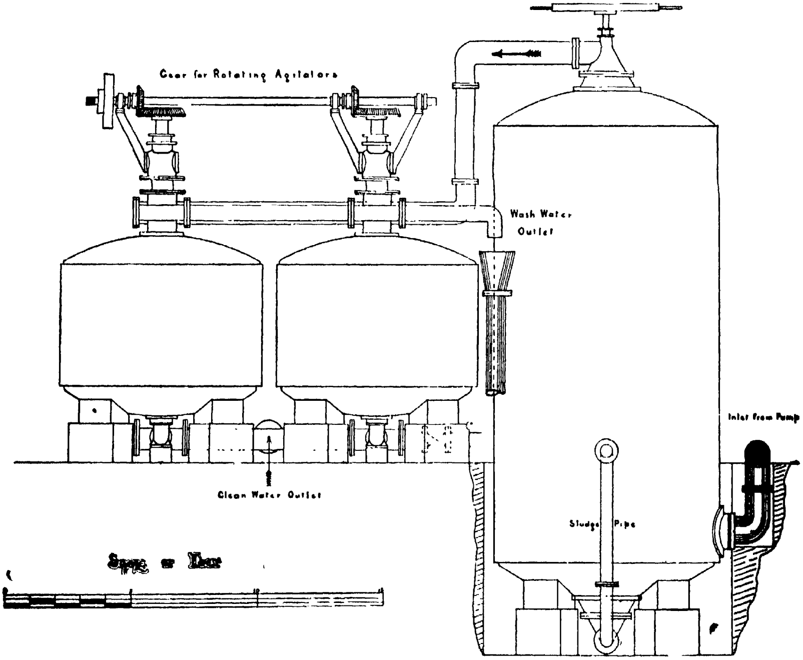


Fig. 24.—Bell's Pressure Tank and Filters.

The lower 3 feet of the chamber serve to collect the sludge, and the bottom of the chamber is in the form of an inverted cone, ending in a sludge valve, and internally there is an arrangement of agitators worked by hand. The sludge which collects is discharged every six hours by opening the sludge valve and rotating the agitators for about five minutes, the pumping being meanwhile continued. This would give an approximate discharge of 2500 gallons of liquid sludge.

As will appear later, there is a resistance to the escape of the effluent from the settling chamber, with the result that the contents are constantly under an average pressure of 15 lbs. This, the inventors claim, greatly increases the deposition of solid matters in the chamber.

The effluent from the settling chamber is further purified by filtration through Bell's Filters, of which there are four, so that each deals with 7500 gallons per hour. Each filter is an enclosed cylindrical vessel of mild steel about 4½ feet high and 8 feet in diameter, and thus the liquid is passing through with a velocity of 4¾ inches per minute, or at a rate of 1340 gallons per square yard per hour. The filtering material consists of silver sand, nearly 3 feet in depth, on a perforated floor of peculiar construction. The whole area of the floor is composed of conical strainers shaped like the rose of a watering-can. Each rose is 6 inches in diameter on its perforated upper surface, is filled with pebbles to prevent the escape of the sand, and communicates below with the general outlet of the filter (see Fig. 25).

In working the filter the effluent from the settling chamber is forced through the sand from above by the action of the pump, the pressure, like that in the settling chamber, averaging about 15 lbs., but getting greater as the filter gets clogged.

The cleansing of the filters is brought about by agitation of the sand in a strong current of water. Power-driven agitators on a central axis are provided in each filter, and these are hollow and perforated so as to allow a strong current of water to be passed through them into the midst of the filtering medium. They are also studded with conical projections so as to form rakes for stirring up the sand. Each filter is cleansed for about five minutes every six hours by reversing the current of water and passing the filtered liquid upwards through the sand by the aid of the full force of the pump, or at the rate of 30,000 gallons per hour. This upward flow is discharged into the sand both through the roses in the floor of the filter and through the hollow arms of the agitators. These are at the same time set in motion, so that the sand is thoroughly scrubbed in a powerful current of water and freed from adhering solid matters. This process is continued for about five minutes until the discharge becomes clean, and yields therefore from each filter about 2500 gallons of very liquid sludge.

The washing water from the cleansing of the filters and the sludge from the settling chamber are discharged to settling tanks, of which there are two, each 19 feet by 23 feet by 4½ feet deep, and one discharge from the settling chamber and each of the four filters was found to be sufficient to fill both the sludge tanks to a depth of 2½ feet, which would amount to some 14,000 gallons. The whole operation of sludging the settling chamber and the four filters lasts from twenty minutes to half an hour every six hours, and during this time the purification process is at a standstill. After the sludge has settled in the tanks, which it does in a few hours, the top water is discharged by outlets 18 inches above the bottom of the tanks into the outlet pipe for the purified refuse. It should be conveyed into the preliminary settling ponds to be circulated again for treatment. The settled sludge accumulates to a depth of 1½ feet in a fortnight or three weeks, and is then discharged to two sludge lagoons, where further settlement takes place. The supernatant water, which should also be conveyed back to the settling ponds, is run off to the stream, and some moisture evaporates, so that after a week or two the sludge has

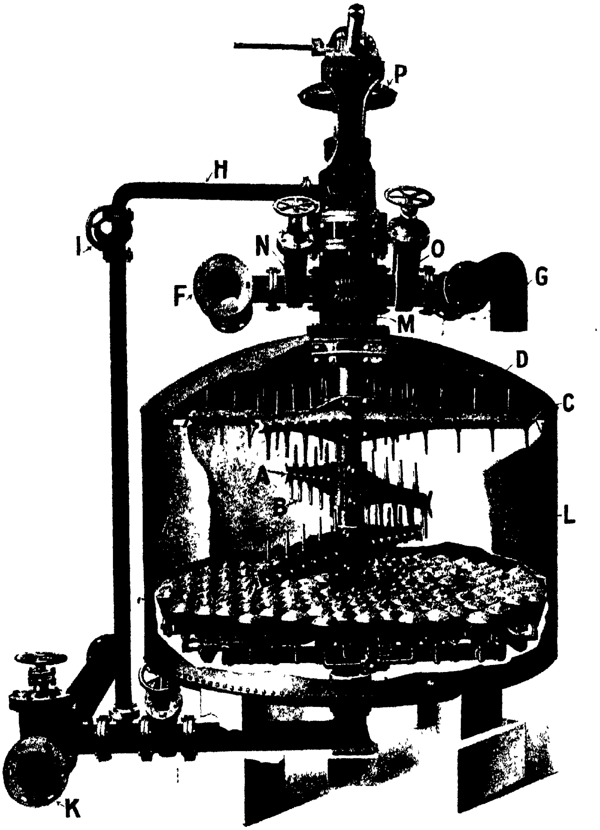


FIG. 25. —Bell's Pressure Filter. View of internal arrangement.

A —Valves in wash arms.
B —Rakes on wash arms.
C—Hydraulic hollow wash arms.
D—Hydraulic hollow shafts.
E —Perforated strainers.
F—Inlet pipe for dirty water.
G —Wash-out pipe for cleaning.
H—Top pipe.
I—Vertical wash valve.
K—Outlet for filtered water.
L Steel filter shell.
M - Top block on shell.
N—Inlet valve for dirty water.
O—Wash-out valve.
P—Bevel wheels.

dried sufficiently to be carted away. In a week this sludge amounts to ten cartloads.

As has already been stated, the water-softening plant is an exact duplicate of that for the treatment of trade refuse, except that there is only one set of sludge lagoons for both. It is worked at the same rate, 30,000 gallons per hour, but owing to the salts in the well water and the greater quantity of precipitants used, the volume of sludge produced is two or three times as large, only requiring one week to accumulate to a depth of 1½ feet in the sludge tanks. The chemicals used are 20·8 parts of lime per 100,000 and 9·1 parts of soda.

Two series of samples have been taken from both sets of the apparatus, and analyses are given in Tables XLI., XLII., and XLIII. The whole of the samples retained a bluish colour, although it was very faint in the effluents from the water-softening plant. The colour in the purified dyewaters could no doubt be to a great extent removed by the use of a larger quantity of precipitants, as it is indeed in the effluent from the water-softening plant. The settling chamber for the dyewaters is evidently not large enough to permit of the settlement of the suspended solids, which are of a light flocculent nature. If the chamber were duplicated so as to reduce the velocity of the liquid by half, much better results would be obtained.

The chief defect in the works seems, however, to be the want of regular cleansing of the preliminary settling dams. The sludge in these putrefies, and, rising to the surface, becomes broken up and drawn into the apparatus by the pumps, while the sulphuretted hydrogen set free interferes with the precipitation process and appears as an impurity in the final effluent. These dams should be sub-divided, so that any part could frequently be put out of use and thoroughly cleansed, and if this were done the rest of the apparatus would no doubt be capable of producing much better results and of dealing with a larger quantity of refuse.

The cost of purifying the dyewaters in this instance is difficult to ascertain, but the patentees, Messrs Bell Bros., estimate that a plant to deal with 100,000 gallons in twelve hours would cost £1000. This would cover the pressure settling chamber, the filters, the tanks for precipitants with the accompanying pump, and the main pump for lifting the refuse. There would have to be added to this the cost of the storage tanks from which the dyewaters would be pumped, and the necessary sludge tanks. The labour required for such a plant Messrs Bell Bros. estimate at two to three hours, and the chemicals at 10d. to 1s. 8d. per day, but these figures appear to be rather under the mark.

Watson's Plant.—At Livingstone Mill, Batley, the Co-operative Wholesale Society, Ltd., have constructed works for the purification of their liquid trade refuse. Designed by H. B. Watson, Ltd., the works were brought into operation in September 1910, and have since been in constant operation with uniformly good results. The trade carried on

TABLE XLI.

SAMPLES TAKEN AT BOWLING DYEWORKS (BELL'S APPARATUS), FROM PROCESS FOR TREATMENT OF TRADE REFUSE.

(*Results expressed in parts per 100,000.*)

Sample of	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Alkalinity (as Na_2CO_3).	Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).			Total.	Permt.	Tempy.
Refuse entering plant	185·40	11·60	3·40	173·8	153·4	1·13	0·22	0·56	6·75	trace	28·4	26·9	1·5
Filter effluent	181·12	5·92	1·84	175·2	157·0	1·05	0·11	0·34	5·49	trace	33·3	33·3	0·0
Sludge from settling chamber	215·80	49·00	21·60	166·8	147·4	1·03	0·70	1·51	10·59	trace	29·9	11·8	18·1
Sludge from filters	346·30	172·70	60·00	173·6	155·2	1·02	2·42	4·64	22·35	trace	37·1	12·5	24·6
Top water from sludge-settling tanks	145·24	6·24	0·24	139·0	122·8	0·48	0·13	0·47	4·15	trace	28·4	25·7	2·7
Refuse entering plant	198·10	18·70	6·10	179·4	161·8	1·45	0·27	0·37	9·12	trace	41·5	29·5	12·0
Filter effluent	172·36	2·56	1·28	169·8	149·8	1·02	0·08	0·22	6·47	trace	42·2	13·6	28·6
Sludge from settling chamber	270·60	101·20	46·60	169·4	151·4	1·04	1·88	4·01	22·60	trace	48·9	9·8	39·1
Sludge from filters	337·60	168·60	67·10	169·0	145·0	0·91	1·97	4·89	31·13	trace	53·0	13·9	39·1
Top water from sludge-settling tanks	159·40	6·40	2·20	153·0	139·0	0·90	0·17	0·28	6·22	trace	42·2	12·8	29·4

TABLE XLII

SAMPLES TAKEN AT BOWLING DYEWORKS (BELL'S APPARATUS), FROM WATER-SOFTENING PROCESS.

(*Results expressed in parts per 100,000.*)

Sample of	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Alkalinity (as Na_2CO_3).	Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).			Total.	Permt.	Tempy.
Water entering plant	124·64	4·64	2·56	120·0	105·4	0·36	0·09	0·29	1·64	42·40	45·7	29·7	16·0
Filter effluent	108·24	0·24	0·16	108·0	99·2	0·39	0·07	0·23	1·60	29·68	14·9	7·4	7·5
Sludge from settling chamber	3298·00	3194·00	3031·40	104·0	94·0	0·40	1·33	3·14	18·30	3392·00	221·0	74·3	146·7
Sludge from filters	633·00	523·00	481·20	110·0	97·6	0·38	0·49	1·11	6·60	530·00	44·3	16·3	28·0
Top water from sludge-settling tanks	107·00	7·60	6·32	99·4	90·0	0·25	0·08	0·20	1·08	31·80	31·3	23·6	7·7
Water entering plant	124·20	3·60	1·36	120·6	108·6	0·65	0·10	0·38	1·46	39·22	40·7	22·8	17·9
Filter effluent	118·16	3·76	2·80	114·4	102·0	0·56	0·09	0·32	1·91	31·80	22·8	14·9	7·9
Sludge from settling chamber	237·40	124·00	115·40	113·4	100·4	0·52	0·15	0·63	2·66	148·40	51·5	26·4	25·1
Sludge from filters	1154·80	1038·60	980·80	116·2	104·8	0·55	0·63	2·05	10·82	1086·50	94·0	30·0	64·0
Top water from sludge-settling tanks	114·20	7·20	4·32	107·0	97·4	0·58	0·09	0·35	1·23	37·10	37·6	31·3	6·3

at this mill is the manufacture of tweed and worsted coatings and suitings, and the liquid refuse is from the processes of piece scouring and dyeing, but the first discharge from the scouring machines is conveyed for the recovery of grease to a separate set of purification works, leaving only the washing-off water to be treated along with the dyewater in the works described below. The dyestuffs used for dyeing are synthetic indigo (in the bisulphite process) and various other coal-tar dyes, and a little extract of myrobalans. In the processes, town's water and well water (after being softened) are used in about equal quantities, and the volume of refuse liquids dealt with is about 7500 gallons per day, exclusive of the thicker piece-scouring refuse.

Table XLIII.

SLUDGES TAKEN AT BOWLING DYEWORKS.

(*Results expressed in parts per cent.*)

Sample of	Moist Sludge.			Dry Solids.*		
	Moisture.	Organic and Volatile Matter.	Ash.	Organic and Volatile Matter.	Ash.	Nitrogen (Kjeldahl).
Sludge from refuse treatment:						
From settling chamber . .	99·78	0·05	0·17	21·69	78·31	1·177
From filters	99·65	0·13	0·22	37·86	62·14	1·634
From settling chamber . .	99·73	0·07	0·20	26·83	73·17	1·866
From filters	99·66	0·13	0·21	37·17	62·83	1·718
Sludge from water softening:						
From settling chamber . .	96·70	0·17	3·13	5·23	94·77	0·107
From filters	99·37	0·05	0·58	8·56	91·44	0·235
From settling chamber . .	99·76	0·02	0·22	9·10	90·90	0·484
From filters	98·85	0·07	1·08	5·99	94·01	0·225
Sludge from lagoons:						
As discharged from settling tanks	89·15	4·13	6·72	38·06	61·94	1·46
After draining off top water .	72·14	5·21	22·65	18·71	81·29	0·64
Being carted away . .	56·25	2·76	40·99	6·31	93·69	0·25

* The figures are calculated from an analysis of the moist sludge.

The crude liquids are first discharged to an underground receiving tank in the mill yard, which is 18½ by 13½ feet and 10 feet deep (15,600 gallons), and from this they are lifted by a centrifugal pump to the purification works. The comparatively large capacity of this tank serves the useful purpose of mixing the various waste waters thoroughly, and the pump draws from the bottom of the tank, so that there is no appreciable settlement of solids. The pump is belt-driven from convenient shafting, and an apparatus is provided in the form of a float which rings a bell to warn the engineer when the receiving tank is full. Pumping is kept up for six or eight hours each day, so as to make the flow through the purification tanks as uniform as possible.

Lime is used to neutralise and precipitate the refuse and is supplied in the form of milk of lime. The lime mixer is a circular tank similar to that shown in Fig. 53, in which beaters or paddles, driven from the same shafting as the pump, keep the contents stirred. At the bottom a large outlet is provided through which from time to time any solids which settle from the lime can be removed. The lime is placed in the tank, in bulk sufficient for a day's use, in a small cage in which stones and undissolved pieces of lime are retained, and water is run in from a tap. The resulting milk of lime is passed into the rising main between the sump and the purification works, where it becomes thoroughly mixed with the refuse.

As will be plainly seen from Figs. 26 and 27, the purification works are compact and occupy little ground space (9 yards by 9 yards). The liquids are first received in a shallow compartment (having a capacity of 332 gallons) above the tanks proper, and in this the heavier solids are deposited. Flowing over a wide sill the liquids pass into the larger of two settling tanks, which is 16½ feet by 13 feet and 7 feet deep, and holds 9400 gallons. Flowing over the submerged wall between the tanks the refuse passes into the smaller tank, which holds some 3400 gallons. In this tank there is a wooden partition extending to within a short distance of the bottom, and the refuse passes under the partition and rises at the other side to pass upwards through a straining filter of fine wood shavings before escaping by the effluent outlet.

The floors of the tanks slope to the centre, and sludge valves are fixed to enable the precipitated sludge to be drawn off to the sludge filter, which is 25 feet by 9 feet, or 25 square yards in area. The filtering medium is 18 inches in depth, and consists of clinker riddled free from dust, the coarsest material being laid on the concrete floor, the finer above, and on the top a layer of very fine material about ½ inch thick. Some sludge is run off from the tanks every day, being forced out by the head of water above it. In dry weather it takes three or four days to dry sufficiently to be removed from the filter by spade, and after further drying on the ground adjoining it is carted away to a tip.

These works, as has been said, give good results while dealing with the comparatively small volume of 7500 gallons per day. They were, however, designed to deal with twice this amount, and no doubt are quite capable of doing so, as the volume at present treated is all passed through in six or eight hours each day, the pump only being in action for that period. The advantage of having a large sump or receiving tank, equal in this case to three days' flow of refuse, has already been pointed out. The total capacity of the settling tanks too is comparatively large, being nearly equal to two days' flow, and this allows time for the settlement of solids. It means, in fact, that the effluent on any one day has been chiefly produced from the refuse of the previous day, which, after settling all night, is displaced from the tanks by the fresh refuse entering. It is somewhat difficult to estimate the maximum amount of refuse with which a plant of this size could deal effectively, but if it were worked continuously at the rate at which pumping now proceeds, then 24,000 gallons could be purified daily. The difficulty of dealing with liquid sludge such as is here produced is very frequently under-estimated, and it would certainly be better in this case to have another sludge filter, so that one could be resting for cleansing purposes while the other is in use.

The cost of such a plant is not great. From information given by the manager of the mill it appears to be as follows:—

Capital cost—		
Tanks, filters, pump, pipes, and fittings	£425	
Sump	40	
Total . .	£465	
Working cost per week—	s.	d.
Labour (1 hour per day)	2	6
Lime	2	0
Sludge removal	2	6
Total . .	7	0

Analyses of samples of the crude refuse and of the effluent are given in Table XLIV.

Archbutt-Deeley System. — The Archbutt-Deeley method of water softening has also been applied with great success to the purification of dyewaters. At the Cheapside Mills of Messrs J. T. and J. Taylor, Ltd., Woollen Manufacturers, Batley, a large plant, erected by Messrs Mather and Platt, Ltd., Salford, has been in successful operation for over four years, dealing with 400,000 gallons per day. The plant and its results were described in a paper read to the Health Congress at Leeds by W. Rushby, the firm's chemist (see *The Medical Officer*, 22nd July 1909, p. 117).

The refuse, which is typical of the Heavy Woollen Trade, amounts to 400,000 gallons per day, and consists of two portions, of which 30,000 gallons is from scouring processes, taken after the grease has been extracted by treatment with a slight excess of acid ; the great bulk, however, is from piece dyeing. The dyes used are chiefly acid and substantive colours, together with tannin, ferric sulphate, and bichromate of soda, so that the refuse is always slightly acid, and contains tannin, ferric salts, chromium compounds, colouring matter, sodium salts, and organic matter from wool. Much is in suspension in the form of dark blue tannate of iron, spent myrobalans, and wool fibre (flocks). The water used is derived largely from the stream, and is very hard ; a considerable proportion, however, is town's water, which is very pure.

The whole of the refuse has to be lifted 30 feet, and this is done by an 8-inch centrifugal pump, which has a capacity of 60,000 gallons per hour, and is made of a special gun metal to resist the action of acids.

TABLE XLIV.

SAMPLES TAKEN AT LIVINGSTONE MILL, BATLEY (WATSON'S PLANT).

(*Results expressed in parts per 100,000.*)

Nature of Liquid.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Alkalinity (in terms of CaO).	Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Total.	By Filtrate.		Total.	Permt.	Tempy.
rude refuse .	85·8	21·4	5·1	64·4	46·6	1·42	0·23	0·76	4·33	2·53	nil	15·0	8·1	6·9
rude refuse .	162·1	44·1	15·4	118·0	90·8	0·77	0·50	1·26	11·93	6·52	trace	12·0	4·4	7·6
inal effluent .	101·1	2·8	2 5	98·3	78·1	..	..	..	1·49	..	trace	41·4	11·8	19·6
inal effluent .	80·9	0·6	0·6	80·3	65·3	..	..	..	2·00	..	2·2	25·4	23·9	1·5
inal effluent .	103·7	4·1	1·8	99·6	78·0	0·99	0·04	0·17	0·82	0·66	30·2	70·3	33·5	36·8
inal effluent .	83·6	3·0	2·0	80·6	68·6	0·62	·10	0·36	1·58	1·21	6·16	28·5	19·1	9·4

The pumped refuse passes through flock recovery apparatus like those shown in Figs. 41, 42, and 43, into large iron tanks, six in number, and each of about 25,000 gallons capacity, which are filled in turn.

The only reagent used for precipitation is milk of lime. For 20,000 gallons, the working capacity of each tank, 36 lbs. of quicklime are needed on the average, the cost of which at £1 per ton is about 4d., or ⅕d. per 1000 gallons. The lime precipitates fatty matters, neutralises the acidity, and also produces by its action on the ferric salts in the refuse a hydrated iron oxide which greatly assists in the deposition of organic matter.

The lime-milk is made in two small wooden tanks, each of about 200 gallons capacity, with a perforated false bottom of iron; it is carried into the channel conveying the refuse, into which it squirts through a perforated pipe. This method of adding the lime saves time, and, what is more important, ensures absence of acid in the large iron tanks. As soon as the large tank is about full, air is blown in for five minutes by means of a steam injector through perforated pipes at the bottom of the tank. The old and new precipitates are thus intimately mingled by the thorough agitation, and this is found to produce a much more perfect final deposition. The settlement is quick, and a clear liquid is ready to be run off after one hour, almost free from suspended matter, but generally slightly tinted, especially if certain very soluble dyestuffs are being used. The tank can be emptied in fifteen minutes by means of a floating discharge pipe, but the more slowly this is done the less is the precipitate at the bottom disturbed. The time occupied is, therefore, for filling, twenty minutes; agitating, five minutes; settling, sixty minutes; running off, thirty minutes; so that in two hours 20,000 gallons have been treated in one tank.

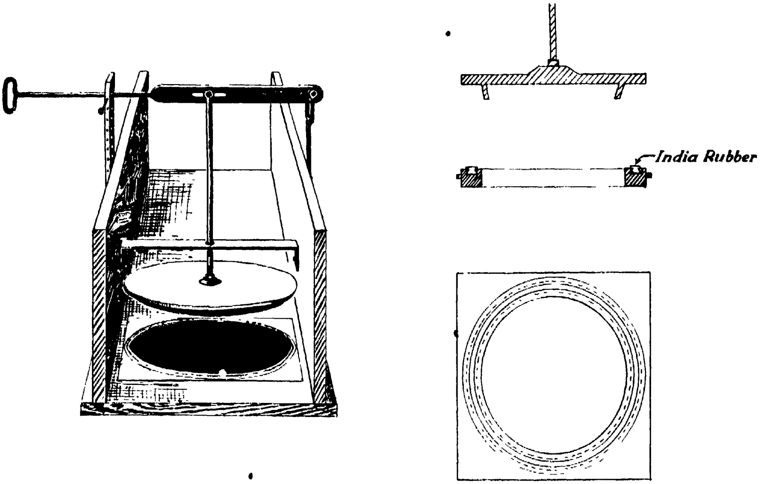


Fig. 28.—Mr Crothers' Valve.

Every few days a portion of the sludge is run out into a sump, which also receives the sludge from a water-softening plant. From this it is raised into a tank for settlement, the clear top water run off, and the remaining sludge filter-pressed ready for tipping. Thirteen and a half tons of sludge cake containing 60 per cent. moisture are produced monthly. The elevating of the mud and the pressing are done by compressed air, the plant for this portion of the work having been supplied by Messrs S. H. Johnson & Co. A very efficient valve used for admitting the refuse to the various tanks has been designed by the manager, Mr Crothers. After considerable trouble with slides and penstocks, it has been found that this contrivance, very simple in construction and use, ensures entire absence of leakage (see Fig. 28).

The considerations which led to the adoption of the Archbutt-Deeley principle in this case were that:

1. The refuse, which varies in composition every few minutes, is averaged in the tank before treatment.
2. Each tankful can receive separate attention and treatment.
3. In the event of any mishap, it is confined to one tank, and the whole process is not interfered with.
4. The great simplicity of the apparatus.
5. The whole process is open and visible.
6. Square tanks are used, thus economising space.
7. The water is not lifted much higher than the top of the tanks, which are 10 feet deep, while in many plants the lift is 40 feet.
8. And, most important, the rate of settling of the precipitate is remarkably quick.
9. The working capacity is great in proportion to space occupied and cost of plant.

Samples of the refuse before and after treatment have been analysed from time to time, and the results of the analyses are given in Table XLV. It will be seen that the purification effected is very satisfactory, the reduction in suspended matters and oxygen absorbed being very marked.

At another mill where a similar plant is in use dealing with 60,000 gallons per day, the refuse includes wool-washing and piece-scouring refuse from which the grease has been recovered by the usual acid treatment, the washing-off waters after piece scouring which are considered to contain too little grease to be worth recovery, and the waste waters from the dyeing of woollen and worsted fancy pieces. The dyewares used are mainly alizarines and wood extracts.

In this case the plant consists of a large receiving tank capable of holding rather more than a day's flow, into which the refuse is pumped; two precipitation tanks, each of 14,000 gallons capacity; and a small tank, divided into two compartments for containing the chemical precipitants, which has a capacity of 150 gallons. These tanks are all constructed of wood. The reagents used are lime and alumino-ferric, about 8 lbs. of each being added to the contents of one large tank. The results obtained with this plant are shown in Table XLV. The capital cost of the works, including pumps, pipes, and fittings, amounted roughly to £1000, so that interest and depreciation can be taken at £100 per annum: the cost of the precipitants works out at $\frac{3}{14}$d. per 1000 gallons, or 12·8d. per day: labour and steam are reckoned at £50 per annum: and, taking all these into consideration, they amount to 2·2d. per 1000 gallons. In reckoning this cost the profit on the grease recovery has not been taken into account.

The Archbutt-Deeley plant can be, as is shown by these two examples, very successfully used for the purification of dyewaters. Its adoption, however, is only advisable in dyeworks which are large enough to warrant

TABLE XLV.

DYE REFUSE TREATED BY ARCHBUTT-DEELEY PROCESS.

(Results expressed in parts per 100,000.)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Total.	By Filtrate.	Total.	Permanent.	Temporary.
Cheapside Mills.													
Crude refuse	264·20	59·20	6·30	205·0	147·0	0·26	0·94	1·57	17·90	...	85·0	85·0	0·0
Effluent	184·08	1·08	0·88	183·0	146·0	0·21	0·11	0·34	0·81	...	67·0	61·0	6·0
Crude refuse	196·80	28·20	3·20	168·6	130·4	0·45	0·40	1·07	14·44	6·12	79·8	78·2	1·6
Effluent	174·60	0·60	0·50	174·0	141·6	0·46	0·14	0·33	3·04	2·90	80·6	66·6	14·0
Crude refuse	199·60	50·20	11·20	149·4	116·0	1·37	0·43	0·98	16·38	6·20	75·0	62·8	12·2
Effluent	152·20	1·20	1·00	151·0	128·2	1·69	0·07	0·36	2·84	2·82	61·3	57·5	3·8
Second Mill.													
Crude refuse	53·36	21·36	18·56	32·0	25·8	2·97	0·07	0·83	0·82	0·27	14·7	13·6	1·1
Effluent	42·56	0·96	0·80	41·6	35·8	2·53	0·02	1·39	0·16	0·15	17·4	16·4	1·0
Crude refuse	52·16	20·16	17·36	32·0	27·0	3·01	0·05	0·37	0·84	0·72	12·7	12·7	0·0
Effluent	42·76	2·96	2·32	39·8	32·0	3·15	0·04	0·24	0·26	0·26	13·4	13·3	0·1
Crude refuse	53·60	21·90	19·20	31·7	25·7	3·33	0·07	0·83	0·76	0·58	11·8	11·5	0·3
Effluent	40·10	3·30	2·80	36·8	30·2	2·94	0·05	0·88	0·23	0·27	14·2	11·8	2·4

the employment of a special manager of the purification works as the process is one which needs constant attention.

Indigo Dyeing.—This branch of dyeing produces refuse which differs somewhat from ordinary waste dyewaters and requires rather special treatment. Although in other trades it has been pointed out that the cost of purification may often be met by the recovery of valuable bye-products, there is no such return to be looked for from the treatment of ordinary dyewaters; the most that can be expected is to purify the refuse so that the effluent can be used again. The waste waters from an indigo dyehouse, however, are an exception to this, and from them it is possible to recover a large amount of the indigo.

Dyeing with indigo is one of the oldest processes of the dyer's art. Ages ago it was practised in the East, and our own forefathers before the Romans visited these shores were in the habit of staining their skins with woad, which contains a small proportion of indigo. Indigo is extracted from a large variety of tropical plants growing chiefly in India, and during recent years it has been chemically produced from coal tar, when it is called synthetic indigo to distinguish it from the natural product. It is a pigment of the well-known dark blue colour, but in this form it is insoluble in water, and it must be converted into indigo white, a substance readily soluble, before it can be used for dyeing wool or cotton. The indigo white is taken up by the fibre, and on exposure to the air is again converted into insoluble indigo blue.

There are several methods of producing the indigo white, or reduced indigo. In the oldest method, the woad vat process, the indigo is robbed of oxygen by means of a fermenting or slightly putrefying mixture of vegetable substances. According to Professor Hummel (*The Dyeing of Textile Fabrics*, p. 306), a woad vat of some 1500 gallons is made up with:

	lbs.
Indigo	33
Woad	660
Bran	22
Madder	5 to 33
And dry slaked lime	25

whilst the Badische Anilin und Soda Fabrik in their handbook on Indigo give the composition of a vat holding 800 gallons as:

	lbs.
Synthetic indigo, S. 20 per cent.	20 to 45
Woad	150
Bran	10
Madder	10
Soda	5
Lime	3

A second method, the hydrosulphite or Read Holliday process, brings about the same result by more direct chemical action. In this, a vat of 1000 gallons capacity may contain, according to Dr M. Liebert (*Indigo M.L.B.*, p. 30):—

Indigo blue M.L.B., 20 per cent.	130 lbs.
Quicklime	12 „
Bisulphite, 56° Tw.	$14\frac{1}{2}$ gallons.
Zinc dust	20 lbs.

A third method, the ammonia process, has recently come more into use. In this process a vat of 2000 gallons may contain:

Indigo B.A.S.F., 20 per cent.	60 lbs.
Hydrosulphite B.A.S.F.	9 „
Strong ammonia liquor	9 gallons.
Glue	8 lbs.

In all these processes fresh materials are added from time to time as the vat contents become exhausted by the dyeing operations. In the woad vat the continual addition of the fermentive materials and the impurities added with them, or produced during the fermentation, bring about a state of matters in which the vat contents, although still containing much indigo, are so impure that they can no longer be used for dyeing. The liquid portion is then sometimes transferred to a fresh vat, but more often run down the drain. The sludge in the bottom of the vat is thrown on the waste heap, or sometimes stirred up and discharged with the liquid. The analyses in Table XLVI. show the grossly polluting character of such discharges. They also show the great waste of indigo which takes place.

The latter methods, especially the ammonia process, are of advantage in greatly lessening the waste of indigo and the amount of polluting refuse which has to be disposed of by the dyer. These vats can be used for much longer periods, and some ammonia vats are said never to be discharged.

The methods of using these various processes are very much alike. In yarn and piece dyeing, the goods, which have been previously wetted, are immersed in the liquid in the dye vat and are afterwards passed through rollers which squeeze out any excess. Exposure to the air then causes the oxidation of the reduced indigo and produces the dark blue colour. To remove any excess of indigo the pieces are washed, sometimes in water alone and sometimes with the addition of fuller's earth, soap, myrobalans (myrabs), or acid, but always finally with large quantities of clean water.

The liquid refuse, therefore, from the process of piece dyeing consists of the contents of the vats when they are discharged and of the daily discharge of washing waters. The analyses show the composition of these liquids. Besides being too polluting to be discharged to a stream, they contain large amounts of waste indigo. In a paper read before the Yorkshire Section of the Society of Dyers and Colourists on 20th February

1902, by Mr Edward Halliwell, F.I.C., who was then head of the laboratory of the West Riding of Yorkshire Rivers Board, detailed analyses were given showing that the amount of indigo lost in the washing-off waters was 8 per cent. of the total amount used. The figures given in the accompanying tables, when compared with those he obtained, would seem to indicate that the loss is often much greater.

In dyeing unspun wool loss of indigo takes place in another way. The wool when taken out of the vat carries with it large quantities of loose indigo, and although sometimes part of this is washed off in slightly acidulated water, usually a large proportion remains entangled in the wool during the after-processes of carding, spinning, and weaving. This indigo is removed from the cloth in the process of scouring with soap, and when the soapy liquids are treated for the recovery of grease the indigo passes into the magma and is retained in the cake after the grease has been pressed out. In this process, therefore, as well as in piece dyeing, there is a great loss of indigo.

The recovery of this waste indigo should present no insuperable difficulty. It has been carried out successfully by several of the cotton dyers in Lancashire. Mr R. A. Tatton, M.I.C.E., in a paper read before the Institution of Civil Engineers (*Proceedings*, 1900, vol. 140), in describing the purification works at the dyeworks of Messrs Sydall Bros., Ltd., Chadkirk, gives the following description of the recovery process adopted there:—

> "The separate recovery of indigo is generally adopted now at works where any considerable quantity is used, and is a very remunerative process—the value of the products recovered at these works amounting to about £1200 a year on a total consumption of about £4000 worth of the raw material. The indigo is recovered from the solid which settles at the bottom of the dye vats, and also from the wash water, through which the pieces are passed after being dyed. The wash waters are first precipitated in tanks under the floor of the works with alumino-ferric and caustic soda, the top water is drawn off by means of a valve with a floating arm, and the solids, together with those from the dye vats, are pumped up into a tank where they are treated chemically; this separates the pure indigo, which is used again in the dyehouse."

In one dyehouse in Yorkshire (Glen Dyeworks, Todmorden, Cornholme Dyeing Co., Ltd.), where cotton warps are dyed, the recovery of indigo from the waste waters has been undertaken by Mr Lishman, and has brought about a saving of 20 per cent. in the total amount used. The first washing of the dyed warps is accomplished by passing them through a vessel containing 2000 to 3000 gallons of water. In this, most of the loose indigo is deposited, and the resulting sludge is from time to time discharged into a sump which also receives any overflow from the vats themselves or their contents when they are discharged as spent. From the sump the indigo sludge is pumped into elevated wooden tanks, where it is reduced and the liquid clarified by settlement, the clear solution of reduced indigo being returned to the vats. The ordinary wash waters are passed through a special settling tank on their way to the purification works which have been provided for the whole of the dyehouse refuse. In this tank

TABLE XLVI.

SAMPLES TAKEN AT INDIGO DYEWORKS.

(*Results expressed in parts per 100,000.*)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.)		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Alkalinity (in terms of NaOH).	Indigo.
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Total.	By Filtrate.		
From Vats.												
Top liquor from exhausted woad vat	1896·0	73·6	33·0	1822·4	948·4	2·34	16·44	29·72	145·74	85·14	*704·9	19·9
Stirred-up contents of exhausted woad vat	9628·8	7844·0	4726·0	1784·8	702·8	3·81	64·83	123·94	596·50	83·16	*763·2	193·6
Stirred-up contents of exhausted zinc vat	2168·8†	1571·6	1205·8	597·2	551·2	1·90	5·60	13·68	154·40	17·00	slight	21·2
Stirred-up contents of woad vat (in use)	...	...	...	...	...	...	...	...	...	...	...	106·2
Stirred-up contents of zinc and bisulphite vat (in use) . . .	1408·6	184·6	36·4	1224·0	994·8	0·11	11·56	16·61	187·60	108·40	456·0	107·0
Stirred-up contents of zinc and bisulphite vat (in use) . . .	...	...	...	...	...	...	...	...	...	...	...	161·2
Stirred-up contents of ammonia vat (in use) . . .	2004·2	36·6	7·2	1967·6	1793·6	98·00	10·50	16·45	270·92	225·06	*636·0	27·4

Washing Waters (after dyeing Worsteds).											
Rinsings after removal from woad vat	136·1	14·7	6·0	121·4	74·6	0·35	0·88	1·41	10·93	8·04	23·6	10·9
First discharge after washing with fuller's earth, etc. . . .	445·3	189·5	109·5	255·8	114·2	0·58	3·62	3·79	108·04	54·97	10·4	51·4
Discharge after twenty minutes' washing off	79·0	11·6	5·6	67·4	50·0	0·08	0·38	0·59	5·31	3·13	12·0	4·5
Discharge after forty minutes' washing off	70·1	5·7	2·0	64·4	44·8	0·14	0·23	0·29	2·58	1·23	12·4	2·3
First discharge after washing with fuller's earth, etc. (after ammonia vat)	175·4	136·4	124·7	39·0	26·4	0·014	0·359	0·666	2·48	0·31	*13·2	nil
Discharge after five minutes' washing off	80·4	40·4	37·4	40·0	27·4	0·005	0·131	0·255	0·91	0·20	*11·1	nil
Discharge after twenty-five minutes' washing off	48·9	9·3	7·7	39·6	27·6	0·014	0·071	0·206	0·52	0·22	slight	nil
Glen Dyeworks (where Cotton Warps are dyed).												
Water from tank used for first washing	1049·4	12·6	1·0	1036·8	994·0	0·56	2·08	3·10	66·40	63·60	333·4	10·6
Discharge from second washing .	858·4	2·4	0·1	856·0	866·0	0·06	0·86	1·42	54·00	51·60	222·0	3·1
Discharge from soap washing . .	36·4	18·4	2·2	18·0	12·6	nil	0·08	0·27	3·20	2·30	nil	0·6
Stirred-up contents of recovery tank	6850·8	180·4	57·2	6670·4	6274·4	0·42	13·32	20·86	595·60	544·00	1652·0	70·0
Sediment from settled wash waters .	1462·4	299·2	173·6	1163·2	1161·6	...	...	...	184·00	92·00	282·0	84·2†

* Alkalinity in terms of Na_2CO_3.

† Containing zinc 373·6.

the indigo settles, and the resulting sludge, which consists almost entirely of indigo washed out of the goods, is passed back into the dye vats.

There appears to be no reason why equally effective measures should not be adopted for the recovery of indigo from the waste waters from the dyeing of worsteds. From the tables of analyses it will be seen that the amounts of indigo present in these waters are practically the same as in the case of cotton dyeing (see Table XLVI.).

The waste indigo from wool dyeing is chiefly found, as has been stated, in the pressed magma cake resulting from grease extraction. There it is so intermixed with grease that it cannot be easily recovered directly. There are, however, numerous works now in operation for the extraction of the grease from magma cake by means of a solvent such as benzine or carbon bisulphide. It should be quite practicable by vatting the degreased cake to dissolve out the indigo and afterwards to recover it by oxidation, as was mentioned in the discussion on Mr Halliwell's paper.

TABLE XLVII.

SAMPLES OF SLUDGES TAKEN FROM INDIGO DYEWORKS.

(Results expressed in parts per cent.)

Nature of Sample.	Moisture.	Organic and Volatile Matters.		Ash.		Total Nitrogen (Kjeldahl).		Indigo.	
		On Moist Sludge.	On Dry Sludge.	On Moist Sludge.	On Dry Sludge.	On Moist Sludge.	On Dry Sludge.	On Moist Sludge.	On Dry Sludge.
Sediment in exhausted woad vat . . .	75·34	9·43	38·23	15·23	61·77	0·38	1·53	1·12	4·56
Sludge cake from mixed dyehouse refuse.—									
After six weeks' air-drying . . .	..	..	..	..	..	..	..	..	5·90
After one week's air-drying . . .	92·42	3·94	51·98	3·64	48·02	0·10	1·32	0·10	1·32
After three weeks' air-drying . . .	84·40	7·80	50·00	7·80	50·00	0·19	1·28	0·24	1·56
Taken from sludge filter . . .	69·15	..	..	..	..	..	..	0·25	0·81
Pressed cake* from seak indigo magma . .	24·46	72·11	95·46	3·43	4·54	..	..	6·23	8·24

* Containing grease 37·41 per cent. (on dry).

Owing to the present low prices the value of the indigo thus recoverable is very much less than it was before the introduction of synthetic indigo, but the sums paid annually for indigo are still very large, and if 20 per cent. can be recovered by simple and inexpensive processes such as have been outlined, and at the same time the polluting matters discharged to the streams materially reduced, the results should be satisfactory both to the manufacturers and the Rivers Authorities.

If the indigo is not recovered from the spent contents of the indigo vats and the first washings of the dyed goods, it passes on to mix with the general refuse of the dyeworks, and is then found in the sludge obtained by the settlement of such refuse. This sludge generally comes not only from the after-processes of indigo dyeing, when it may contain fuller's earth, myrobalans, etc., but also from dyeing with aniline and other colours. In such mixed sludge there is naturally a much smaller proportion of indigo than is found in that from the exhausted vats and first washings, the proportion varying with the nature and extent of the processes, other than indigo dyeing, carried on at the dyeworks. From the analyses given (Table XLVII.) it will be seen that even such mixed sludges may contain from 1 to 6 per cent. of indigo, an amount which ought certainly not to be wasted. The recovery of the indigo from this mixed sludge might not be an economical process, and it would therefore be advisable to recover as much as possible from the stronger wash waters before their admixture with the refuse from other operations.

The waste waters from indigo dyeing, when mixed with other discharges from a dyehouse, are not found to interfere with any of the ordinary purification processes. The indigo reaching the purification works is always in the insoluble form, and as such settles readily. In these cases, however, care should be taken that the settling tanks are frequently and completely cleansed in order to prevent their contents becoming septic, when the septicised matters would reduce the indigo and render it soluble.

Sulphide Black Dyeing.—Of late years there has been a great development in dyeing cotton and other vegetable fibres with sulphide colours. These are coal-tar derivatives and are dissolved in a solution of sodium sulphide before application to the materials, so that any waste dyewater or washing water is necessarily of a highly polluting character and greedily absorbent of oxygen. There is little need to discharge the contents of the dye vats, as these can be freshened up with additional amounts of the dye and with such substances as sodium carbonate, common salt, or glucose, which last is sometimes added as a reducing agent; when cotton warps are dyed the dye liquor is often circulated through the material in patent dyeing machines, and this process, as has been previously mentioned, considerably aids in using up the dyestuff in the vats; so that the main discharge consists of the washing waters. The first washings can be rendered less polluting by using them for a preliminary soaking of the goods, or can be reduced in volume by using them for making up the dye vats; but in spite of any of these contrivances there remains a discharge of polluting waste waters, highly charged with sulphides, and liable to give off volumes of sulphuretted hydrogen either by ordinary decomposition or when mixed with any acid waters (see Table XLVIII.).

These waste dyewaters are troublesome to purify either by themselves or when mixed with other dyehouse refuse, and if discharged to a public sewer are extremely likely to cause nuisance in the sewers and to interfere materially with the treatment of the sewage. Like the kier liquors of a bleach croft, it is better to treat them separately in the first place, and the following description of works for the purpose, constructed by W. McD. Mackey, F.I.C., at a dyehouse in Bradford, where the refuse waters are afterwards discharged into the public sewer, may serve as an example of the kind of treatment likely to be effective.

In this case cotton warps are dyed in a machine where the dyewaters are circulated through the material under a pressure of 40 lbs. to the square inch. When the dyeing is completed, water is forced through the goods, and the first portion of the washings is returned to the dye-liquor tank, while the bulk is discharged as refuse. The waste water passes into a sump, which is large enough to hold a day's flow of 10,000 gallons, and is pumped into a settling tank of 6000 gallons capacity. When the tank is full, about 20 lbs. of lime and 1 cwt. of copperas are added, and the contents of the tank are agitated by means of air blown in with a steam injector, and then left to settle for several hours. After settlement, the clear top water is discharged through a floating valve to the sewer.

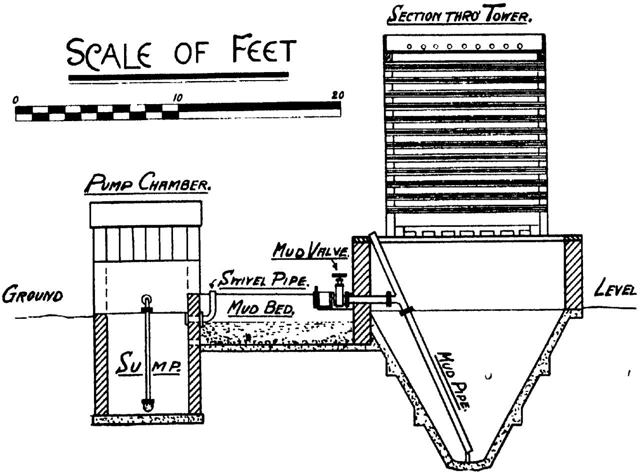
Table XLVIII.

SULPHIDE DYE REFUSE.

(Results expressed in parts per 100,000.)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Alkalinity (in terms of Na_2CO_3).	Hardness (in terms of $CaCO_3$).			Sulphuretted Hydrogen (from Sulphides).
		Total.	Ash.	Total.	Ash.	Total.	Filtrate.		Total.	Permt.	Tempy.	
From Mackey's Plant.												
Crude refuse .	638·5	50·5	4·9	588·0	476·4	179·21	151·05	106·0	3·5	2·5	1·0	..
Do. .	316·4	1·4	0·7	315·0	248·0	93·70	9[illegible]·60	..	1·1	1·0	0·1	21·7
Precipitated and settled refuse	420·1	2·7	2·2	417·4	359·0	59·26	56·15	..	93·3	49·3	44·0	..
Do. .	486·5	12·2	6·4	474·3	424·2	73·20	69·10	..	53·0	16·9	36·1	47·1
From Chambers & Hammond's Plant												
Crude refuse .	809·0	77·8	16·4	731·2	669·2	110·65	53·45	58·3	13·8	3·3	10·5	17·3
Final effluent .	788·7	3·5	0·7	785·2	702·6	34·40	32·70	20·1	18·8	13·0	5·8	15·5

The sludge is let off by a bottom valve to one of four sludge filters, each of which is in the form of a box 11 feet by 5 feet in area and 2½ feet deep. The sides are made of wood and the bottom of expanded metal covered with cocoanut matting, on which is laid about an inch of engine ashes. The sludge is only let off from the settling tank after several tanksful have been precipitated and run off, and each discharge fills one of the sludge filters, which is allowed to drain for several days, when the volume is reduced by two-thirds. The sludge is then removed by spade and thrown on to the adjoining ground to dry in the air before it is carted away, and when air-dried is said to amount to more than 50 tons per annum. As will be seen from the analyses, this treatment effects a large amount of purification, but the effluent resulting, although fit for reception into a sewer, as in this case, would require further treatment before it could be considered fit to discharge into a stream. The treatment by lime and copperas carries down a great deal of the organic matter and the sulphuretted hydrogen, so that the offensiveness of the refuse is to a great extent removed, and it can be purified along with other waste dyewaters.



Section C. D.

FIG. 29.—Patent Trade Effluent Plant. (Chambers & Hammond, Huddersfield.)

In another case works for dealing with refuse of this kind have been constructed with the object of effecting more complete purification so as to produce an effluent fit to be discharged to a stream. These works were designed by Messrs Chambers & Hammond, Huddersfield, and are shown in Figs. 29 and 30; they deal with a flow of 30,000 gallons, produced in a working day of ten hours. The dyewaters are received into a sump, where they are screened. They are raised by a pump to the top of an aerating tower, 10 feet in height, and formed of louvred boards like a water cooler. As the liquid trickles down this tower it is exposed in fine subdivision to the action of the air, with the view of oxidising and rendering inoffensive any free sulphuretted hydrogen. At the base of the aerating tower a block of alumino-ferric is placed as a precipitant, and the liquid is passed through a series of four settling tanks, the lower portions of which are in the form of inverted pyramids. Baffle boards are provided to direct the current of liquid downwards, and the overflow from one tank to the next takes place over a sill extending over the whole width of the tank so as to reduce the velocity of the current. At the outlet of the final tank the liquid has to pass through a filter of fine wood shavings. The tanks are so arranged that the sludge which collects in the pyramidal bottoms can be removed under the hydraulic head of the supernatant water without throwing the tanks out of use. The sludge thus removed is very liquid and is discharged on to sludge beds where the water separates, being partly removed by underdrains and partly allowed to escape by swivel pipes, and is returned to the sump to be mixed with the crude refuse. The sludge pipes in the settling tanks are brought up with open ends to the top of the tank, so that they can be rodded if they become blocked.

The analyses given in Table XLVIII. show the result of this treatment, and it will be seen that, although the removal of suspended solids has been very complete and there has been a marked reduction in the oxygen-absorbed figure, the amount of sulphuretted hydrogen in the effluent is practically the same as in the crude refuse.

Summary.—In reviewing the various methods herein described for the purification of dyewaters, it will be noticed that the dyer can usually look for no profit from the treatment of his waste waters; but although this is true on the whole, there are many ways in which the necessity for treatment has led to economies which have at least partially repaid him. Mention has already been made of the changes in the methods of dyeing, which have at least to some extent been brought about by the necessity of purifying the dyewaters; of the modern dyeing machines, which require much smaller volumes of dye liquor and are more effective in exhausting the colours than the older vats; of the screens by means of which much valuable fibre is recovered; of the recovery of indigo in indigo dyeing, and, finally, of the recovery and re-use of the washing waters. It is in this last direction that the greatest economy is likely to be effected. In every case where the water supply of a dyehouse is limited, and especially where water has to be purchased, it would manifestly be to the dyer's advantage to separate the cleaner washing waters from the rest of his wastes and to purify them, as is done at Bowling Dyeworks (p. 144) and in Waite's plant (p. 136), so as to make them again fit for use in the dyehouse, leaving only the dirtier waters to be treated as refuse.

One problem in dealing with dyewaters is the removal of dissolved colouring matters, but, generally speaking, it will be found that precipitation by the reagents mentioned, especially lime, will be effective in removing colour as well as in causing the deposit of solids. The dyer is to a certain extent protected with regard to the discharge of coloured effluents by the definition in the Rivers Pollution Prevention Act, 1876, Section 20, which says: ". . . 'Polluting' shall not include innocuous discolouration . . . ," and which is also repeated in other Acts; but obviously a discolouration which may be innocuous under certain conditions may be very objectionable in other cases. In practice it is generally found that if all the suspended matters are removed from dyewater, and the effluent is discharged into a running stream of considerable volume, the colour soon disappears; but this is not always the case, for there are certain colouring matters, such as geranium red, used by paper makers, and certain greens, used in the woollen trade, which are extremely persistent, and will stain a stream for miles. Even such persistent colours can be removed by proper treatment; for example, Mr E. Halliwell, F.I.C., has found that although a geranium-red colour persists after precipitation of the waste waters with alumino-ferric, because the colour lake formed with the alumina is soluble in the sulphate present, it can be removed by using aluminium chloride, inasmuch as the colour lake is not soluble in chlorides.

Printing.—The trade refuse from print works (see Table XLIX.) is usually very similar to waste dyewaters. The colouring matter used is for the most part, however, applied to the goods by means of stamps or rollers, and for this purpose it must be thickened with such materials as starch, gum, albumen, or china clay, and as the process depends for its success upon all the apparatus and machinery being kept thoroughly clean, there is a considerable amount of waste water resulting from the washing of tubs, rollers, and "backing cloths," which carries some of the thickening agent with it as well as colouring matter. The goods are also often passed through baths of mordanting liquors consisting of solutions of salts of chrome, iron, alumina, etc., and these are from time to time discharged. There are other waste waters from such processes as cleansing by soaping, eliminating the starch used for thickening with malt extract, bleaching by chlorine, treating with decoction of cow dung to cleanse the white part of the goods, and the frequent washing of the goods thus treated. At most calico printing works, moreover, the cotton goods are bleached before being printed, and the strongly alkaline "boilings," as well as all the other bleach-croft wastes, are discharged with the general refuse.

Apart from the presence of the kier liquor from the bleach croft at calico print works, which it has already been suggested should be dealt with separately, the chief point of difference between the discharge from printing and the waste water from a dyehouse is that the former is liable to contain organic matters, such as starch, gum, albumen, cow dung, and malt extract, and these render this liquid more difficult to purify by chemical precipitation, and more amenable to biological methods of purification.

It is found in practice that the provision of catchpits on the drains from the different departments, and the frequent removal of the solids retained in them, render the mixed refuse much easier to purify and suitable for the application of any of the methods usually adopted for purifying dyewaters.

Stiffening and Loading.—In the finishing of cotton goods there are various processes for the application of stiffening materials, such as starch, size, and mucilage; the goods are often loaded with such substances as china clay and insoluble salts of lime and baryta; in rendering the goods waterproof and non-inflammable various reagents are added, such as salts of alumina, magnesia, and lead for the former purpose, and ammonium phosphate and sodium tungstate for the latter purpose; but as all these substances have a considerable value, and as there is no after-washing of the goods, the only polluting discharges from the processes come from the washing of the various utensils. These are small in amount, and when occurring in connection with bleach, dye, or print works have little effect upon the general discharges, and can be treated along with them. Where they occur separately they can easily be disposed of by evaporating them on the furnace ashes.

In a few of the mills where heavy woollens are manufactured some of the pieces are stiffened by passing them through a strong starch liquor, the excess of which is afterwards washed off in a "dolly" or washing machine. This waste starch liquor (see Table XLIX.), if mixed with soapy scouring refuse, renders the separation of the grease by the ordinary acid method of recovery exceedingly difficult. The starchy liquid in such a case should be dealt with separately, and it can be purified by precipitation with alumino-ferric, settlement, and filtration.

Carbonising and Stripping.—In raw wool there are numerous particles of vegetable material, in the shape of seeds, burrs, and small particles of grass, which have become entangled in the wool while still on the sheep's back. In shoddy, which is woollen fibre which has previously been manufactured, there are frequently considerable amounts, averaging 20 per cent. of its weight, of cotton fibre, and in both these cases the vegetable matter must be extracted by a preliminary process, as otherwise it would appear as specks or blemishes in the finished goods. This process is known as extracting or carbonising, and is essentially a conversion of the cellulose of the vegetable matters, by the aid of acid and heat, into a hydrocellulose, which, when thoroughly dried, is brittle, and can easily be shaken or beaten out of the woollen fibres. When sulphuric acid is used, the wool or shoddy is thoroughly soaked in dilute acid of some 1·03 specific gravity, dried, and passed through a hot-air chamber, the temperature in which is some 80° C. When hydrochloric acid is the carbonising agent the material is exposed to its fumes at a similar temperature, about 20 gallons of spirits of salt being necessary for carbonising a ton of rags. The escaping acid fumes are condensed in a scrubber or water tower. When the wool or shoddy is removed from the carbonising chamber it is willeyed or shaken in a special machine to break up and sieve out the now definition in the Rivers Pollution Prevention Act, 1876, Section 20, which says: ". . . 'Polluting' shall not include innocuous discolouration . . . ," and which is also repeated in other Acts; but obviously a discolouration which may be innocuous under certain conditions may be very objectionable in other cases. In practice it is generally found that if all the suspended matters are removed from dyewater, and the effluent is discharged into a running stream of considerable volume, the colour soon disappears; but this is not always the case, for there are certain colouring matters, such as geranium red, used by paper makers, and certain greens, used in the woollen trade, which are extremely persistent, and will stain a stream for miles. Even such persistent colours can be removed by proper treatment; for example, Mr E. Halliwell, F.I.C., has found that although a geranium-red colour persists after precipitation of the waste waters with alumino-ferric, because the colour lake formed with the alumina is soluble in the sulphate present, it can be removed by using aluminium chloride, inasmuch as the colour lake is not soluble in chlorides.

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It is found in practice that the provision of catchpits on the drains from the different departments, and the frequent removal of the solids brittle vegetable matters. Finally, the acid remaining in the materials must be got rid of, and this is done by repeated washing or steeping in water, to which in some cases soda is added to neutralise the acid. In all cases, however, clean water is used for the final washing.

When shoddy is made from coloured rags the colour often requires to be extracted, especially when the shoddy is to be made into light coloured materials. This is usually effected by "stripping" the colours with sulphuric acid, sometimes aided by an oxidising or reducing agent. The rags are boiled in an acid solution, containing some 15 to 25 per cent. of acid when an oxidising agent is used, and some 1 to 2 per cent. with a reducing agent, and this is afterwards run off and replaced by a weak solution of soda to neutralise the residual acid. The residual soda is then washed out by clean water.

The discharges, therefore, from carbonising and stripping are very similar in character, consisting of the acid liquids, the alkaline neutralising liquids, and the washing or steeping waters, all of which carry with them in suspension and solution some polluting matters which have been extracted from the materials treated. Analyses of these liquids are given in Table XLIX.

The purification of such liquids is quite simple. If they are mixed together, neutralised, and effectively settled, the resulting effluent may generally be discharged to a stream, or may be used in the boilers of the mill. In some cases the effluent produced by treatment of this kind is re-used in the processes, but in such cases the manufacturer generally prefers to use clean water for the final washing of his materials, and this when discharged can scarcely be considered polluting.

Mercerising.—This is a process in which cotton goods are treated under tension with a strong solution of caustic soda in order to give them a permanent silky lustre. Occasionally the soda liquors are discharged after use, but there is no excuse for allowing them to escape into a stream, as the recovery of the soda is very profitable. The liquors are generally concentrated by evaporation and causticised as described on p. 88, when they are again fit for use.

For Bibliography see end of Chapter IX.

CHAPTER IX.

THE TEXTILE TRADES—*continued.*

Piece and yarn scouring—Milling and fulling—Treatment of refuse—Grease recovery very profitable—Purification works at Rowley Mills—Hopton Mills—Flannel manufacture—Blanket scouring—Peel House Mill and Providence Mill—Summary—Bibliography.

Piece and Yarn Scouring.—In the preparation of raw wool, and especially of shoddy, for spinning, considerable quantities of oil or grease must be used, varying greatly according to the nature of the raw material, being, in the case of wool to be spun into worsted yarn, only from 2 to 3 per cent., while, in shorter-stapled wool, and more especially in shoddy mixtures which are being made into lower-class woollen goods, the grease added may be as much as 25 per cent. of the weight of the material. All this grease, with any dirt which may have been taken up in the processes of manufacture, must be removed from the yarn or piece, and although the machinery employed for dealing with different classes of goods varies slightly, the process is practically the same in all cases, consisting essentially of washing with soap, soda ash, or ammonia, or sometimes with fuller's earth.

In the Report of the Royal Commission of 1868 (Third Report, p. 20) frequent mention is made of stale urine, pig's blood, and pig's dung being used as detergents, and at that time also human fæces were used in some mills, but the value of these was chiefly due to the carbonate of ammonia they contained, and they have been almost universally displaced by soda ash (carbonate of soda) and soap. There are still, however, a few old-fashioned mills, especially in the blanket trade, where pig's dung and stale urine are used.

It will be simplest first to describe the processes where soap and soda are employed as detergents. Just as the amount of oil present in the goods varies according to the nature of the material, so does the strength of the seak, or soapy solution, used for removing the oil. For example, in scouring worsted yarns it was found in one case that 6 lbs. of soap were used to scour 100 lbs. of yarn, and in this case no alkali was being used. At another mill, where light worsted goods were being scoured, 6 lbs. of soda ash and 2 lbs. of soap dissolved in 26 gallons of water were used for scouring 100 lbs. of the goods, and this was followed by a second washing in which soap alone was used to the amount of 4 lbs. dissolved in 20 gallons of water. Woollen pieces, especially those which are principally made of shoddy, contain, as has been said, very much larger amounts of grease than yarns or worsteds, and the scouring process is therefore a more severe one. In some cases, indeed, only soda is used in making up the scouring liquid, when 7 lbs. of soda ash dissolved in 30 or 40 gallons of water may be necessary for scouring 100 lbs. of the goods. It has been found that, generally speaking, three pieces, each about 80 yards in length, are scoured together, and that 2000 gallons of water are used in the whole process, but this amount naturally varies according to the water supply available.

As has been stated, the scouring operation is practically the same in every case. The goods are placed in a "dolly" or washing machine, provided with machinery for keeping them constantly in motion, and passing them alternately through the seak prepared as above, and between wooden rollers, which serve to press the seak into the goods and mix it thoroughly with the contained grease. When this part of the operation has continued for some half hour or more, water is turned on and sprayed over the goods as they revolve in the dolly, the outlet of the dolly is opened, and the soapy water allowed to escape, and this "washing-off" is kept up for an hour or more, until the escaping water shows no signs of soap or grease.

Owing to the differences in the goods scoured and in the detergents used, the waste liquids vary greatly in strength, although all are practically of the same nature. The discharges from any one of the processes vary also according to the stage of the washing at which the sample is taken. The first discharge is that of the seak or scouring mixture, with much of the dirt and oil extracted from the goods, and this and the first washing waters are so soapy that in most cases the grease is recovered from them as a valuable bye-product. This greasy water may roughly be estimated at a third of the total discharge; as the washing proceeds, the escaping waters, although less greasy, are still highly polluting, and these may be reckoned as constituting another third of the total; the remaining third consists of cleaner waters which contain very little grease, and may, in some cases, be discharged to a stream without detriment.

Either before or after the pieces have been cleansed by scouring they have to be "milled" or "fulled," a process of felting in which they are submitted to a violent pressing, kneading, or beating in the milling machine or fulling stocks, being first saturated with a strong solution of soap, to which carbonate of soda or fuller's earth is sometimes added. When this milling is done before the pieces are scoured, the grease and soap are all removed in the scouring operation, but when the goods have been scoured before being milled, the soap, soda, or fuller's earth introduced in the milling must be washed out, and this produces refuse very similar to that from piece scouring, although not so polluting.

In certain cases, particularly for the final cleansing of high-class worsted goods previous to dyeing, ammonia is used as a detergent, but this is always done in the dyehouse, and the resulting liquids are only slightly polluting, and can easily be dealt with along with the dyewaters.

In the scouring of carpet yarns fuller's earth is generally used, and the refuse waters cannot be profitably treated for the recovery of the grease. The refuse produced is very similar to that from the scouring of blankets with fuller's earth, and can be purified by the method described on p. 196.

All the above-mentioned soapy liquids are grey and turbid, with a frothy scum, and deposit considerable amounts of solid matter on standing: they soon putrefy, when they turn black and give off offensive smells: they are invariably strongly alkaline in reaction, and if discharged into a stream, they are liable to produce fungoid growths in its bed.

The purification of these liquids is not a difficult matter. The first consideration is whether an attempt is to be made to recover the grease which they contain, and in that case the acid recovery process already described in connection with wool suds is almost invariably adopted. The effluent produced by this acid treatment is, however, very much less polluting than that obtained from wool suds, inasmuch as it does not contain any of the organic matters naturally present in raw wool; nor does it require to be as strongly acid as the wool-washing effluent, for the grease in piece-scouring suds is much more readily separated. If effectively neutralised and filtered, it is generally fit to discharge to a stream.

An excellent plant on this system has been constructed at Rowley Mills, Lepton, by Messrs. Thos. Waite & Co., 3 Hillside Road Works, Bradford, for the occupiers, Messrs G. Beaumont & Sons (see Fig. 31). This firm carries on the business of "finishing" woollen and worsted goods, and the process from which liquid refuse is produced is piece scouring.

The goods or pieces are first scoured in a washing machine with soda ash (carbonate of soda) and soap substitute (a patent alkaline preparation). After this scouring process the pieces are milled with the aid of a solution of soap, and this soap is afterwards washed out in the scouring machines. The amount of grease and soap in the refuse is comparatively small in this case, the goods which are scoured being mostly of light texture and containing little grease.

The whole of the waste waters from the scouring machines, amounting to some 20,000 gallons a day, are conveyed to a sump of 4500 gallons capacity, from which they are pumped into seak tanks for the recovery of the grease. There are three seak tanks, constructed of wood, with a capacity of some 10,000 gallons each. They are fitted with small pipes through which air and steam are blown by an injector in order to thoroughly agitate and mix the contents of the tanks. When a tank has been filled with suds, vitriol is added to the amount of some 10 or 11 gallons, and the tank contents are then thoroughly stirred up by means of injected air for seven or eight minutes. The man in charge then takes a sample of the mixture in a glass vessel in order to ascertain whether the suds are thoroughly "cracked." If not, he adds a little more acid. If too much acid appears to have been already added, he can add a little more of the suds, and a man who is accustomed to this kind of work can effectively separate the grease in the refuse without adding much excess of acid.

After this "cracking," the refuse is allowed to stand in the tanks for some three hours or more until the grease is thoroughly separated from the acid water. The latter is then run off through an outlet about a foot from the bottom of the tank, to be further purified.

The magma or greasy sludge remaining in the tank is run off by a bottom outlet to one or other of four magma filters. The magma, however, is only run off after the tank has been twice filled and the contents "cracked," so that each discharge of magma comes from about a day's discharge of the refuse waters, or 20,000 gallons.

The acid water from the soak tanks is delivered into a wooden neutralising tank of 3500 gallons capacity, and from this is syphoned into another similar tank. The neutralising agent used is milk of lime, which is prepared in a special mixing tank of 440 gallons capacity, and is delivered into the channel which conveys the acid water into the neutralising tanks. The quantity reckoned to be sufficient for neutralising the acid water of one of the soak tanks (10,000 gallons) is about 30 lbs. of quick-lime. This amount is added to a tank full of water (440 gallons) and kept agitated by a mechanical stirrer, worked from a shaft in the mill, and is gradually discharged at the same time as one of the soak tanks. The lime water is thus thoroughly mixed with the acid water in passing through the two neutralising tanks, and any resulting deposit settles in these tanks.

The neutralised liquid passes out of the tanks by a syphon pipe with outlet about 2 feet from the bottom of the second tank, and is conveyed by a wooden trough to a percolating filter 30 feet in diameter, composed of broken stone and ashes about 4 feet deep, and varying in size from 2 inches at the bottom to $\frac{1}{4}$ inch at the top, the effluent from the filter being discharged to the stream.

The distribution of the neutralised liquid on the filter is effected by a patent sprinkler. The liquid is discharged upon a small overshot water-wheel 3 feet in diameter and then distributed by a revolving tubular sprinkler of the common type. The water-wheel drives a shaft with a cog-wheel arrangement, by means of which the revolution of the sprinkler is aided.

When the neutralising tanks are being cleansed most of the liquid contents are run off to the sprinkler filter, the remainder, including the sludge, being discharged on to a small ash filter 9 feet by 6 feet, but this has been found to be much too small, and the liquid escapes from it by an

TABLE L.

PIECE-SCOURING REFUSE FROM ROWLEY MILLS, LEPTON (G. BEAUMONT & SONS).

(Results expressed in parts per 100,000.)

Sample of	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Acidity (as H_2SO_4).	Alkalinity (as Na_2CO_3).	Hardness (in terms of $CaCO_3$)			Fatty Matter.
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn)	Organic (Kjeldahl).	Total.	By Solution.			Total.	Permanent.	Temporary.	
Crude refuse . . .	319·60	99·20	9·55	220·4	120·4	0·32	2·33	4·50	31·77	18·63	..	103·9	...	...	...	139·2
Effluent from seak tank .	343·27	72·57	1·03	270·7	198·6	0·63	1·09	2·05	13·07	2·88	55·5	...	77·9	58·8	19·1	63·3
Effluent from neutralising tank	316·50	54·80	1·40	261·7	199·8	0·55	0·94	2·11	9·95	2·53	44·9	...	71·6	58·3	13·3	45·7
Final effluent . . .	240·57	1·47	0·44	239·1	211·0	0·48	0·27	0·55	1·02	0·69	14·5	...	48·7	43·8	4·9	...

overflow to the stream. With care in letting off the acid water from the seak tanks, the amount of sludge which collects in the neutralising tanks is only very small.

Each of the magma filters is 13 feet by 8½ feet, and composed of furnace cinders 2 feet in depth, with a covering of bricks set with intervening spaces about half an inch in width. The water which drains away from the magma is received into a pump well from which it is intended to be pumped back to the seak tanks. The magma, after draining, is shovelled into pieces of sacking and made into "puddings" in the usual way. These puddings average 12 lbs. in weight each, including the sacking, which weighs 2 lbs., and from each discharge of magma, representing, as has been shown, the daily amount of 20,000 gallons of refuse, some sixty magma puddings are usually made.

Table LI.

SLUDGES TAKEN AT ROWLEY MILLS, LEPTON (G. BEAUMONT & SONS).

(Results expressed in parts per cent.)

Sample of	Moist Sludge.			* Dry Solids.			
	Moisture.	Organic and Volatile Matter.	Ash.	Organic and Volatile Matter.	Ash.	Nitrogen (Kjeldahl).	Total Fatty Matter.
Magma . . .	64·50	34·30	1·20	96·70	3·30	3·14	78·60
Sludge from neutralising tank . .	69·75	17·23	13·02	57·00	43·00	0·69	40·00

* The figures are calculated from an analysis of the moist sludge.

Messrs Beaumont have made an arrangement with a firm of grease extractors who provide the vitriol required in the process of "cracking," and take all the magma made, paying for it at the rate of 15s. per ton net, *i.e.* deducting the weight of the sacking.

Messrs Beaumont state that the total cost of the plant here described, including the alteration of drains inside the mill, was £600. The labour required is that of one man at 23s. per week, or £59, 16s. per annum, and the cost of the lime used as a precipitant amounts to £9 per annum. As against this they receive about £52 a year for the grease. On these figures, allowing 10 per cent. on capital for depreciation and interest, and £5 per annum for the cost of steam used, but excluding the cost of the site, the net annual cost amounts to £82, or 3¼d. per 1000 gallons treated.

A plan and section of the purification works are given in Fig. 31, and in Tables L. and LI. analyses of the refuse at various stages of the purification. On comparing the organic nitrogen and oxygen-absorbed figures in the effluent from the neutralising tank and the final effluent, it is evident that a large amount of purification has been brought about by biological action in the percolating filter.

In the heavy woollen trade, in which, as has been explained, much larger quantities of oil are used, the process of grease recovery is much more profitable. One firm in the Batley trade, making army, railway, and police cloths, which weigh 30 to 40 ounces per yard, has kindly furnished the following particulars. During a year's working 4000 pieces were manufactured, each 80 yards in length, in scouring which 1000 gallons of water were used per piece. The oil used in manufacturing these goods amounted to 59 tons 10 cwts. recovered in the seak plant and re-used, valued at £535, 15s., together with 16 tons 16 cwts. freshly purchased, valued at £261, 2s. 6d. The soap used cost £13, 15s. 4d., and amounted to 14 cwts., of which half, or 7 cwts., may be reckoned as oil, making a total of 76 tons 13 cwts. in all. Forty tons of soda ash were used for scouring, and cost £184, 7s. 10d.

The piece-scouring waters are all passed through a screening apparatus of the kind shown in Fig. 41 (p. 241), and pumped to a grease-recovery plant, very similar to that at Rowley Mills (p. 175), in which the grease is recovered by the aid of sulphuric acid, and the resulting effluent is neutralised by lime and strained through a cinder filter.

The shoddy or greasy waste from the scribbling and carding machines is, in this mill, mixed with the magma and pressed for the recovery of the oil, and thus the amounts of oil recovered and of press cake are increased.

	£	s.	d.
The screening and seak plant, including pumps, presses, and filters, cost	£563	0	0

	£	s.	d.
The lime used in a year	£1	2	0
Labour (one man at 30s. per week)	80	0	0
Vitriol	42	8	0
Steam and town's water (for the hydraulic press)	50	0	0
Cloths for the magma puddings	1	11	0
Annual working cost	£175	1	0

	£	s.	d.
The oil recovered was 59 tons 10 cwts., valued at	£535	15	0
The flocks recovered were 397 stones	8	5	0
49 tons of pressed cake were sold for	22	8	0
Gross annual return	£566	8	0

The profit and loss account may therefore be set out as follows :—

Gross annual return		£566 8 0
10 per cent. for interest and depreciation on £563 .	£56 6 0	
Working costs	175 1 0	
Annual charges		231 7 0
Annual profit		£335 1 0

It will be seen that of the oil used in the processes of manufacture some 77 per cent. is recovered and used over again, and similar figures have been obtained at another mill in the same kind of trade.

At a mill in the Huddersfield trade good works for the extraction of grease from the liquid refuse produced in the process of scouring fancy woollens and worsteds have been erected by the Longwood Engineering Co., Ltd.

Only the thicker suds are treated, as the District Council are preparing a sewage scheme which will deal with the other waste waters from the mill. The suds are passed through large sieve boxes in connection with the washing machines, and afterwards through a patent flock catcher like that shown in Fig. 41 (p. 211), into a pump well or sump, the quantity treated averaging 11,000 gallons per day. From the sump the refuse is pumped to four wooden seak tanks of an average capacity of 3500 gallons. Each tank is fitted with an arrangement of paddles on a central spindle, mechanically driven, and also with a half-inch steam pipe.

A tank is filled with the suds, the necessary quantity of vitriol (about 11 gallons) added, the mechanical stirrer set in motion for about fifteen minutes, steam blown into the liquid for about ten minutes, and the tank contents allowed to settle for about two hours. At the end of this time the grease or magma has risen to the top of the liquid, and the clear acid water is run off from the tank by a bottom valve protected by a sleeve pipe, as described on p. 116. The tank is again filled with suds and the operation repeated, after which the sludge or magma is discharged to a magma filter, of which there are four. There it is allowed to drain until most of the acid water has been got rid of, when it is made into "puddings" by folding it up in pieces of sacking, each parcel weighing about 14 lbs. The puddings are pressed in a steam-heated press, working up to a pressure of 400 lbs. to the square inch ; here the grease and water are pressed out, leaving the solids behind in the form of a magma cake, which is stored and sold.

The firm took very careful observations over a definite period, during which 6512 pieces were scoured, two-thirds woollen and one-third worsted. The average weight of the pieces before scouring was 90 lbs., while the average weight of the finished goods was only 78 lbs., showing a loss of

12 lbs. per piece. Ten thousand pounds of flock or fibre were recovered. The amount of oil used in the manufacture of the goods was 18 tons, and 39 tons of soap were used for scouring, of which half may be reckoned as oil, or a total of 37½ tons of oil. Forty-six tons of shoddy or waste fibre from the carding process were sold, containing 30 per cent. of oil, or 13¾ tons, and 17½ tons of oil were recovered from the suds, or together 31¼ tons, or 83 per cent. of that originally present. The remaining 17 per cent. was lost in the washing-off waters and in the magma cake.

The profit and loss account on the grease recovery is stated as follows:—

Interest and depreciation at 7½ per cent. per annum on cost of building	£6	13	0
Interest and depreciation at 10 per cent. per annum on cost of plant	26	11	0
Wages	34	10	0
Vitriol, sacking, etc.	47	0	0
Steam	8	1	0
Total	£122	15	0
17½ tons oil recovered, at £8 per ton	£140	0	0
10 tons magma cake, at 6s. per ton	3	0	0
Total	£143	0	0
Credit balance for the period in which 6512 pieces were scoured	£20	5	0

Tables LII. and LIII. show analyses of the various liquids and sludges, and from the acidity of the final effluent it is evident that a considerable quantity of acid was being wasted.

In the plant last described, although the works are very effective for the recovery of grease, they are not designed to produce an effluent fit to discharge into a stream. This, however, can easily be accomplished by treating the acid water from the grease-recovery process along with the alkaline washing-off waters, when the two discharges neutralise one another, and the fatty matters they may contain are precipitated and can easily be removed by sedimentation and filtration. This is the plan adopted at Hopton Mills, Mirfield, where a plant for the purification of the waste waters has been erected for Messrs H. Wheatley & Sons by Messrs Kirk & Sons, Architects, Dewsbury. The plant has been at work for nearly six years and constantly giving excellent results.

The manufacture carried on at the mill is that of imitation sealskins and woollen and union piece goods, rugs, blankets, and yarns, and the

TABLE LII.

SCOURING REFUSE FROM MILL IN HUDDERSFIELD TRADE.

(*Results expressed in parts per 100,000.*)

Sample of	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Acidity (as H_2SO_4).	Alkalinity (as Na_2CO_3).	Hardness (in terms of $CaCO_3$).			Fatty Matter.
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Total.	In Solution.			Total.	Permt.	Temp.	
Mixed scouring refuse .	1412·2	713·8	117·4	698·4	423·6	1·11	7·99	15·54	110·6	...	...	303·1	11·1	3·4	7·7	714·0
Washing-off after first scour	102·8	46·8	4·9	56·0	38·8	0·16	0·97	3·69	10·3	...	...	23·3	3·4	3·4	0·0	24·1
Washing-off after second scour	58·7	25·1	3·6	33·6	26·0	0·08	1·00	2·01	3·5	...	...	11·6	6·0	1·6	4·4	8·1
Washing-off after milling .	76·9	35·5	3·0	41·4	26·6	2·60	1·72	4·03	7·6	...	...	18·0	2·5	1·4	1·1	16·2
Water from oil receiver .	403·4	148·5	4·4	254·9	188·0	2·00	0·77	1·85	28·5	...	*140·0	...	75·0	43·5	31·5	127·8
Final effluent . . .	677·6	9·7	0·6	667·9	524·7	0·88	0·28	1·30	6·3	5·14	95·8	...	118·2	113·5	4·7	7·6

* As Oleic Acid.

processes from which the trade refuse is produced are piece and yarn scouring, and dyeing. Only yarn is dyed, ground logwood and bichromate of potash being used in the process, and the dyeing is only occasionally done. The spent logwood is recovered from the dye liquors in a catchpit fitted with a screen, and thus from the dyehouse only the screened dye liquors have to be dealt with in the purification works.

The thicker piece- and yarn-scouring refuse is conveyed to seak tanks for the recovery of the grease. A considerable amount of calf hair is used in the manufacture of imitation sealskins, and this, as it comes from the tanneries, contains lime which has been used in the dehairing process, so that although the dry hair is first carefully "willeyed" or shaken up to remove the dust, the refuse liquids from the scouring of these goods necessarily contain a certain proportion of lime, which by neutralising the acid increases the cost of recovering the grease in the seak plant. The amount of grease to be recovered is also small in comparison with that at most woollen mills, as the goods are largely scoured with urine and soda ash instead of soap.

TABLE LIII.

SLUDGES FROM MILL IN HUDDERSFIELD TRADE.

(*Results expressed in parts per cent.*)

Sample o	Moist Sludge.			* Dry Solids.			
	Moisture.	Organic and Volatile Matter.	Ash.	Organic and Volatile Matter.	Ash.	Nitrogen (Kjeldahl).	Fat.
Magma . . .	57·91	39·43	2·66	93·69	6·31	1·65	76·69
Pressed cake . .	21·98	67·05	10·97	85·94	14·06	4·55	32·39

* The figures are calculated from an analysis of the moist sludge.

The seak tanks, which are constructed of wood, are two in number, each a little over 6000 gallons capacity. They are fitted with air pipes through which air is blown by an injector in order to mix thoroughly the contents of the tanks.

Four magma filters are provided to receive the greasy sludge from the seak tanks. They vary in size, but have a total area of 44 square yards. These filters are composed of engine ashes about 2 feet in depth, covered with a layer of spent logwood from the dye vat, which is renewed each time the magma is removed.

The magma which has been run on to the magma filters is allowed to drain there for two or three days until most of the acid water has been got rid of. It is then removed in the ordinary way, by shovelling, and made into "puddings," enclosed in sacking and weighing about 14 lbs. each. These are put into steam-heated presses worked by hand, and the expressed oil and water are conveyed to a tank, where the oil rises to the top and can be skimmed off, while the watery liquid is discharged to the purification works. The oil is purified in another tank by the addition of a further quantity of acid and by being agitated by live steam, and here also, after settling, the watery contents are run off from the bottom of the tank to the purification works, while the oil is retained and re-used in the manufacturing processes.

The magma cake from the oil presses amounts to 7 or 8 cwts. per week, and is sold for 6s. per ton.

The grease in the scak tanks is separated as usual with vitriol, and the acid tank effluent and the acid water separated from the grease, as well as the liquid draining from the magma filters, are passed on to the purification works proper, along with the remaining refuse from the mill. This consists of the final washings of the pieces and yarn and the dyewaters when dyeing is being done.

The further purification works consist of settling tanks and filters. The tanks are two in number, each 38 feet by 27 feet by 5 feet deep, and together have a capacity of 64,000 gallons. In each tank the refuse is received in a wooden trough which runs the whole length of the top wall of the tank. Each tank is subdivided by a cross wall through which the liquid passes by seven openings at a depth of 4 feet from the surface of the liquid, and has a wooden trough along the whole length of the end wall for receiving the tank overflow and delivering it into the outfall channel.

By these means the liquid is delivered into the tank over a sill extending the whole width of the tank, its direct flow is baffled at the centre of the tank and directed downward, and the tank effluent is collected over a similar sill. The velocity of the current through the tank is thus equalised over the whole width and reduced to a minimum. By directing the liquid underneath the mid-wall the tank contents are more thoroughly mixed, and any floating matter is retained, and in addition a scumboard fixed before the collecting trough keeps back floating leaves and any further scum formed in the second compartment.

The two tanks can be used either separately or in series, and either of them can be put out of use for cleansing. They are provided with floating arm outlets by means of which the liquid part of the contents can be discharged while the sludge is retained. The bottom of each tank is dished to a sludge outlet. In ordinary working the tanks are used in series and the refuse is continuously flowing through them. When one tank is being cleansed the top water is run off down to the sludge and the sludge swept out, and meanwhile the other tank is used.

For the tank effluent two filter beds have been provided, each having

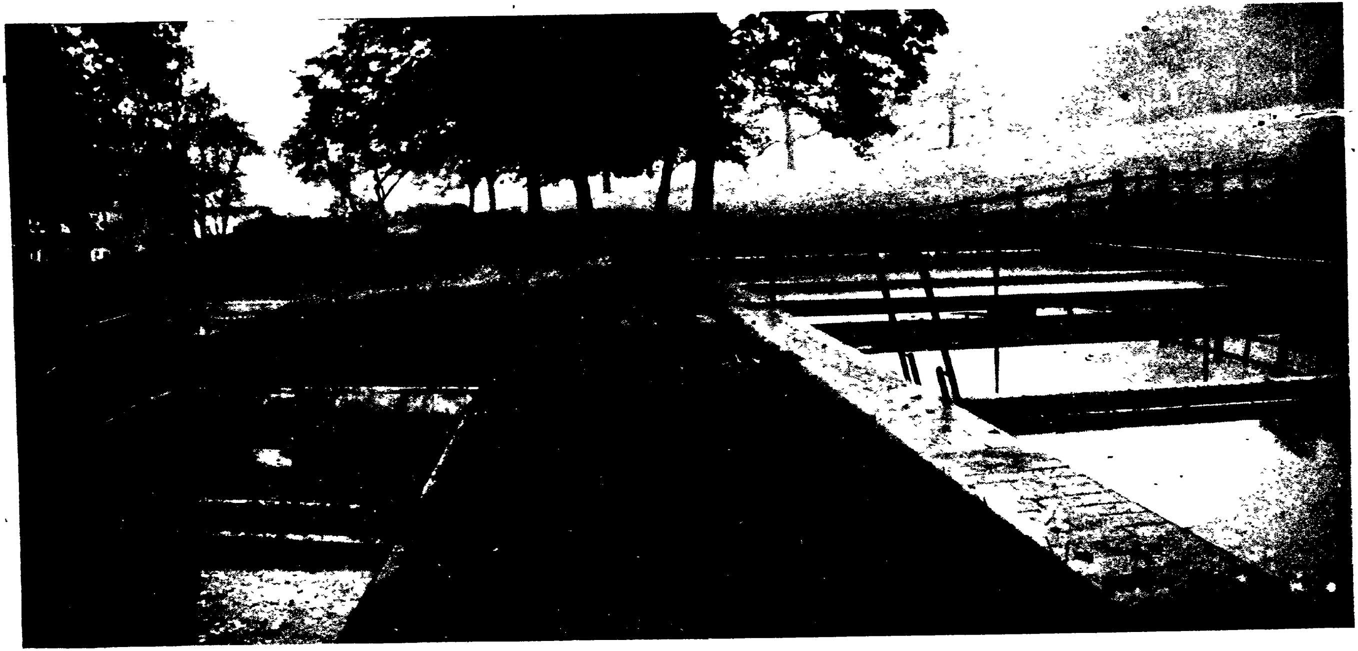

FIG. 33.—Purification Works at Hopton Mills, Mirfield.

an area of 85 square yards. The filtering material is engine clinker 2 feet 6 inches in depth, mostly consisting of pieces between 2 inches and half an inch in diameter, but with a fine layer on the surface of pieces varying from a quarter to one-eighth of an inch. Two sludge filters have also been provided, each about 37 square yards in area and constructed like the top-water filters. The effluents from both sets of filters are discharged to the stream.

The works are intended for the use of a chemical precipitant if that should be necessary, but so far no precipitant has been found necessary, the acid discharges from the seak plant being neutralised by the alkaline washing-off waters, and the mixture of the two liquids bringing about a precipitation.

The daily amount of refuse is estimated approximately at 15,000 gallons, and of this amount about a quarter is passed through the seak plant, but the works are capable of dealing with larger quantities.

Over a given period Mr Wheatley took very careful observations of the amount of work done, the cost of treatment in the seak plant, and the value of the oil recovered, and finds that, in a fortnight when some 120 pieces of sealskins and 35 pieces of woollen and union goods were dealt with, the results for the grease-recovery part of the process were as follows:—

Vitriol, 23½ cwts., at £1, 17s. 6d. a ton .	£2	4	0
Wages	1	10	0
Depreciation, steam, and interest on capital expended in seak and grease-recovery plant	1	14	0
	£5	8	0
Against this were:			
16 cwts. of oil, at 9s. per cwt.	£7	4	0
Magma cake, 15 cwts., at 6s. per ton .	0	4	6
	£7	8	6
Balance . .	£2	0	6

At this rate of working this part of the plant would yield a profit of £50 per annum after all expenses have been paid.

The total cost of the plant was £953, including £73 for the seak tanks and magma filters, £80 for the oil-pressing plant, and £800 for the purification works proper, without making any allowance for the value of the site. The labour required in attention to the latter works amounts only to 2s. 6d. per week, or £6, 10s. per annum, and the interest and depreciation may be taken to be £80 per annum (in addition to the allowances for the grease-recovery plant). So that at the above rate of working

Table LIV.

SAMPLES TAKEN AT HOPTON MILLS, MIRFIELD (HENRY WHEATLEY & SONS).

(*Results expressed in parts per 100,000.*)

Sample of	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Alkalinity (as Na_2CO_3).	Acidity (as H_2SO_4).	Hardness (in terms of $CaCO_3$).			Fat after Acidification.
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).				Total.	Permt.	Tempy.	
Thicker suds	1133·4	557·2	95·5	576·2	446·1	8·58	7·47	19·16	67·7	271·3	...	...	...	...	426·8
Seak-tank effluent	1019·4	63·2	2·8	956·2	821·6	9·22	1·99	4·41	17·9	...	23·2	186·5	145·2	41·7	79·0
Washing-off water	494·8	207·8	53·5	287·0	231·0	3·62	2·59	7·68	28·1	120·8	...	38·5	9·4	29·1	136·9
Dye waste	1339·7	66·5	15·0	1273·2	726·8	12·99	15·60	25·82	101·6	...	trace	703·0	650·5	52·5	...
Refuse from presses	747·5	73·7	1·0	673·8	227·6	3·84	6·05	14·76	35·3	...	193·5	613·0	500·0	113·0	64·9
Refuse from grease purification	4162·6	294·0	12·4	3868·6	278·6	4·16	7·00	12·76	47·5	...	3405·5	3592·5	3592·5	0·0	269·2
Magma filter effluent	785·2	1·6	0·3	783·6	674·0	8·70	1·10	2·73	7·9	...	10·4	152·4	137·0	15·4	...
Refuse entering settling tanks	309·2	133·7	47·0	175·5	145·3	2·92	1·55	4·61	17·3	76·3	...	28·4	5·7	22·7	76·5
Effluent from settling tanks	215·6	6·8	2·4	208·8	185·5	2·25	0·36	0·75	2·9	...	trace	49·0	38·9	10·1	...
Final effluent	260·4	1·9	0·6	258·5	237·5	1·91	0·30	0·55	1·6	...	...	50·2	39·1	11·1	...

the actual net cost per annum is £36, 10s. Under present conditions this amounts to nearly 2d. per 1000 gallons, but it must be borne in mind that the plant is designed to deal with twice the present average volume of refuse.

Fig. 32 shows a ground-plan of the works, which has been kindly furnished by Mr Kirk, and a photograph is given in Fig. 33. Samples have from time to time been taken of the various liquids before and after purification, and the analyses are given in Tables LIV. and LV.

It should be mentioned that the effluents are discharged into a very small stream. It is clean but ochrey above the mill, and was formerly always grossly polluted by the mill refuse, but now shows no apparent pollution after receiving the effluents.

TABLE LV.

SLUDGES TAKEN AT HOPTON MILLS (HENRY WHEATLEY & SONS).

(*Results expressed in parts per cent.*)

Sample of	Moist Sludge.			* Dry Solids.			
	Moisture.	Organic and Volatile Matter.	Ash.	Organic and Volatile Matter.	Ash.	Nitrogen (Kjeldahl).	Fat after Acidification.
Air dried sludge from sludge filters . .	47·29	30·82	21·89	58·47	41·53	3·70	22·72
Magma as put into "puddings" . .	48·76	48·86	2·38	95·34	4·66	0·41	85·84
Pressed magma cake .	30·00	61·52	8·48	87·88	12·12	5·61	40·25

* The figures are calculated from an analysis of the moist sludge.

As has been explained, where worsted pieces are scoured the amount of grease present is comparatively small, and many manufacturers do not make any attempt to recover it. In such cases the purification of the waste waters is usually effected by precipitating the greasy matters and other impurities by means of lime and alumino-ferric or similar precipitants, and by afterwards settling out the solids in tanks and filtering the tank effluent.

Flannel Manufacture.—A similar course is usually adopted at mills where light flannel goods are made. The following is a description of purification works on this principle at a mill employed in the manufacture of flannels.

The polluting processes in connection with the manufacture are three in number—wool washing, wool (and cotton) dyeing, and piece scouring, but it is from the piece scouring that the bulk of the polluting liquids is discharged.

The wool washing is scarcely comparable to that in other branches of the wool trade, for only wool which has been previously washed is used, and the cleansing process it undergoes is a second washing to enable it to take dyes readily. It loses, on an average, 16 per cent. of its weight in the washing. The wool is placed in a perforated metal casing, which is immersed in a small tank filled with hot soapy or alkaline liquid, and after being thoroughly soaked it is rinsed twice or thrice in clean water. The liquid in the tank is used over and over again, being strengthened from time to time with fresh alkali or soap, and is only discharged at long intervals of a month or two. It thus becomes highly polluting, but is only small in volume. The water in which the wool is rinsed is only slightly polluting, the final washings being nearly pure water.

The dyeing is done "in the wool," and aniline colours, logwood (with chrome mordant) and indigo (in woad vats) are all used, but the indigo dyeing is usually done on other premises by "country" dyers. The loose wool is immersed in a vat or dye pan of the hot dye liquid and allowed to soak for some time. It is then usually withdrawn from the dye vat and placed in another tank filled with clear cold water, in order to cool the material and to wash off excess dye. The dye pans are sometimes emptied after each operation, but frequently, and especially when aniline colours are used, are only partially run off and filled up again with fresh dye water. In the indigo vats the woad method of dyeing is generally used, and the vats are only discharged at long intervals. The dyewaters, especially those containing logwood or indigo, are very polluting, but the washing-off waters are frequently only slightly fouled.

After the goods are manufactured they are milled and scoured. Milling, as has been stated, is a felting process by which the interstices between the fibres of the cloth are closed up and the goods are made soft and fleecy, shrinking greatly in the operation. It is done either by beating the pieces in stocks or by passing them repeatedly through a milling machine, soapy liquid being added in either case to moisten them. The amount of liquid used in this process is small, and usually all absorbed by the goods. After being milled the pieces are scoured in a washing machine with a considerable quantity of hot soapy water, with which soda ash, or carbonate of soda, is generally mixed. When the washing machine containing the goods has been run for some time with this soapy liquid, the liquid is discharged and the pieces are washed off in the same machine in several quantities of clean water until all the soap has been washed out. The scouring liquid when discharged is thick and almost jelly-like on cooling, and very highly polluting, the first washing-off water is little better, but the final washings consist of almost clean water.

All the waste waters, amounting to 7500 gallons per day, are discharged to a sump, from which they are pumped to the purification works. This sump has a capacity of some 1300 gallons, so that it allows of a considerable mixture of the different kinds of refuse, and this is certainly an advantage in the treatment. From the sump the liquids are pumped

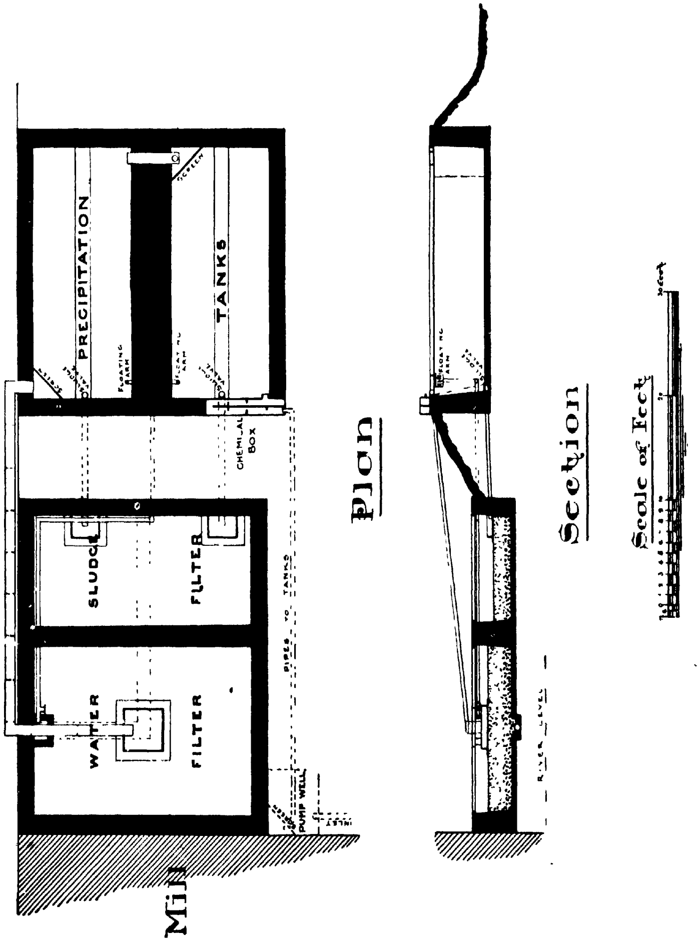

FIG. 34.—Purification Works at a Flannel Mill.

a height of 10 feet to a settling tank of 9000 gallons capacity, passing into it through a channel 10 feet long, fitted with bafflers, where the precipitants are added. This tank is fitted at the end with a perforated zinc scumboard, and discharges into a second exactly similar tank, the outlet pipe from which delivers on to an ash filter of 40 yards area by an open wooden channel fitted with bafflers. Each tank is fitted with a floating arm outlet which also delivers on to the filter, and with a sludge in number—wool washing, wool (and cotton) dyeing, and piece scouring, but it is from the piece scouring that the bulk of the polluting liquids is discharged.

The wool washing is scarcely comparable to that in other branches of the wool trade, for only wool which has been previously washed is used, and the cleansing process it undergoes is a second washing to enable it to take dyes readily. It loses, on an average, 16 per cent. of its weight in the washing. The wool is placed in a perforated metal casing, which is immersed in a small tank filled with hot soapy or alkaline liquid, and after being thoroughly soaked it is rinsed twice or thrice in clean water. The liquid in the tank is used over and over again, being strengthened from time to time with fresh alkali or soap, and is only discharged at long intervals of a month or two. It thus becomes highly polluting, but is only small in volume. The water in which the wool is rinsed is only slightly polluting, the final washings being nearly pure water.

The dyeing is done "in the wool," and aniline colours, logwood (with chrome mordant) and indigo (in woad vats) are all used, but the indigo dyeing is usually done on other premises by "country" dyers. The loose wool is immersed in a vat or dye pan of the hot dye liquid and allowed to soak for some time. It is then usually withdrawn from the dye vat and placed in another tank filled with clear cold water, in order to cool the material and to wash off excess dye. The dye pans are sometimes emptied after each operation, but frequently, and especially when aniline colours are used, are only partially run off and filled up again with fresh dye water. In the indigo vats the woad method of dyeing is generally used, and the vats are only discharged at long intervals. The dyewaters, especially those containing logwood or indigo, are very polluting, but the washing-off waters are frequently only slightly fouled.

After the goods are manufactured they are milled and scoured. Milling, as has been stated, is a felting process by which the interstices between the fibres of the cloth are closed up and the goods are made soft and fleecy, shrinking greatly in the operation. It is done either by beating the pieces in stocks or by passing them repeatedly through a milling machine, soapy liquid being added in either case to moisten them. The amount of liquid used in this process is small, and usually all absorbed by the goods. After being milled the pieces are scoured in a washing machine with a considerable quantity of hot soapy water, with which soda ash, or carbonate of soda, is generally mixed. When the washing machine containing the goods has been run for some time with this soapy liquid, the liquid is discharged and the pieces are washed off in the same machine in several quantities of clean water until all the soap has been washed out. The scouring liquid when discharged is thick and almost jelly-like on cooling, and very highly polluting, the first washing-off water is little better, but the final washings consist of almost clean water.

All the waste waters, amounting to 7500 gallons per day, are discharged

These purification works were constructed under the advice and supervision of Mr R. W. Oddy, of Rochdale, who has constructed a large number of similar works in the West Riding and in Lancashire. They cost in all £252, including the drains, pump well, pump, etc., and Mr Oddy considers the plant capable of dealing thoroughly with 9000 gallons a day.

Taking the interest and depreciation at £25 per annum, the labour at £7, the cost of precipitants at £13, and the cost of steam at £5, the annual cost of treatment amounts to £50, or 5·3 pence per 1000 gallons treated. The comparatively large cost per volume treated is due to the relatively large cost of works dealing with small volumes of refuse. In this case, for example, the interest and depreciation on the plant account for 2·6 pence, or half the total cost per 1000 gallons. Moreover, in a small mill such as this it would not pay to put in a grease-recovery plant, the return from which in a larger mill would at least pay for the cost of precipitants. In some other flannel mills, the manufacturers recover the grease and find it profitable to do so, and even when the grease recovery yields no direct profit, it may do so indirectly, inasmuch as the acid effluent produced may serve to neutralise and precipitate the rest of the mill refuse (see p. 186). Analyses of samples of the waste waters and of the final effluent are given in Table LVI.

TABLE LVI.

REFUSE FROM FLANNEL MANUFACTURE.

(*Results expressed in parts per 100,000.*)

Nature of Liquid.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	
River water used	14·4	...	...	14·4	9·6	0·005	0·027	0·11	0·15
Well water used	23·4	.	..	23·4	21·5	0·023	0·002		0·006
Wool-washing liquid	2604·0	883·2	54·1	1720·8	1226·4	9·89		24·83	62·23
First wool rinsing	29·6	5·2	0·2	24·4	18·8	0·11	0·116	0·65	0·72
Second ,, ,,	19·2	3·0	0·1	16·2	11·4	0·054	0·066	0·23	0·50
Cotton dye water	...	trace		471·0	432·0	0·49	..	2·50	18·80
,, ,, washing-off	80·0	.	.	80·0	71·0	0·005	...	0·53	1·77
Chrome liquor	160·0	67·0	2·0	93·0	75·0	0·30	...	1·70	5·20
,, washing-off	45·0	4·0		41·0	32·0	0·62	...	0·39	0·94
Logwood liquor	100·0	13·0	1·0	87·0	58·0	0·14	...	1·36	27·90
,, washing-off	35·0	4·0	1·0	31·0	23·0	0·07	...	...	1·93
First wash, piece scouring	786·6	506·0	17·0	280·6	118·6	11·4	...	8·03	44·40
Second ,, ,,	156·0	94·4	8·4	61·6	41·6	1·53	...	2·06	9·20
Third ,, ,,	133·0	77·0	12·0	56·0	36·0	0·094	...	1·17	5·48
Mixed crude waste	293·6	196·6	23·6	97·0	60·0	2·10	1·20	4·06	15·30
Mixed tank effluent	98·2	8·8	6·0	89·4	83·4	1·15	0·13	0·43	0·88
Mixed final effluent	94·6	3·0	1·7	91·6	83·0	1·00	0·096	0·37	0·74

Blanket Scouring.—The scouring of blankets may be considered to come midway between wool washing and piece scouring, inasmuch as the raw wool is often carded, spun, and woven before it undergoes any cleansing process, and the refuse discharged thus contains the organic matters of wool-washing suds, as well as the oil and the soap or other detergent of piece-scouring suds.

In blanket scouring two methods are employed. In the first the goods, as they come from the looms with their natural impurities and the oil added in carding, are scoured with soap and soda like ordinary piece goods and afterwards milled in a soap solution, which has then to be washed out with considerable volumes of clean water. This is the method adopted at the Peel House Mill of R. T. Riley & Son.

At this mill there is also a carbonising process, in which, as has already been described (see p. 170), vegetable matters are removed from the wool by an acid treatment, and the acid is afterwards washed out or neutralised with soda. The thicker scouring suds are pumped to two seak tanks, where the grease is recovered. The washing-off waters after scouring and milling are all drained to a separate pump well, from which they are raised to a settling tank, receiving on the way a dose of sulphuric acid to ensure the separation of the grease. The acid effluent from the seak tanks is also conveyed to this settling tank, where a large amount of grease separates and is dealt with like the magma from the seak tanks. The tank effluent overflows on to two shallow filters, which are, however, used more as settling tanks than as filters, and from these a further amount of grease is obtained. The effluent from these filters is passed through further filters, of which there are four in two series. The filters are composed of broken stone upon a foundation of stone pitching, and covered with a 3-inch layer of ashes from the mill furnaces.

The cost of the works, which are not very substantially built, was £260, not including the cost of pumps and magma press. This at 10 per cent. for interest and depreciation amounts to £26 per annum. One man gives his whole time at £60 per annum, and pumping and repairs are estimated at £15 per annum. Seventy tons of vitriol are used annually, but 25 tons of this are used in carbonising, leaving 45 tons at a cost of £90 per annum used directly for grease recovery. The total annual cost is therefore £191. The quantity of oil recovered is 29 tons per annum, worth £232, and this is recovered from 14 tons of oil used in the carding and spinning, 12½ tons in the soap used, and some oil contained in the wool. In the magma presses 33 tons of cake are produced, worth £8, 5s. per annum. The whole process, therefore, is remunerative.

Table LVII. shows the nature of the refuse produced and the results of its treatment, and the purification works in use are shown in Fig. 36.

In the second method of blanket scouring, fuller's earth is used as a detergent instead of soap. The goods from the loom are milled in fulling stocks with fuller's earth and water and afterwards thoroughly scoured with

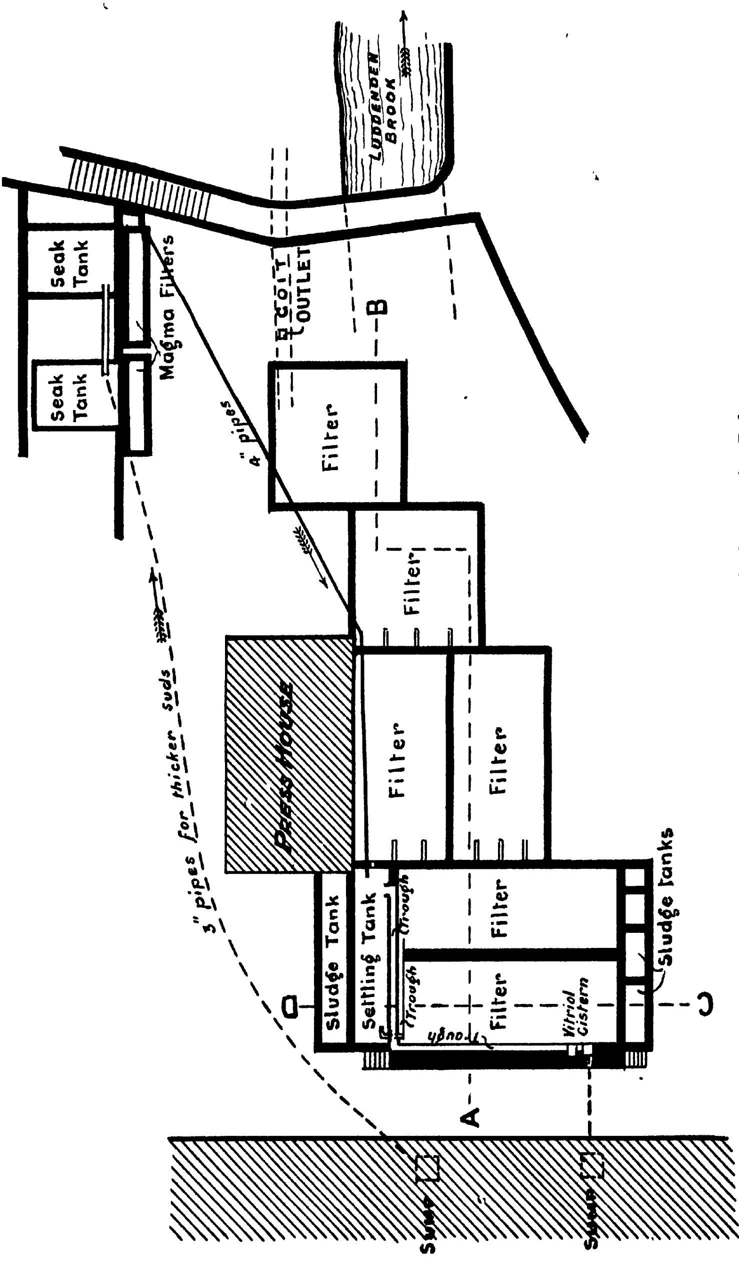

FIG. 36.—Purification Works for Blanket-scouring Refuse.

TABLE LVII.

BLANKET-SCOURING REFUSE.

(Results expressed in parts per 100,000.)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Alkalinity (as Na_2CO_3).	Acidity (as H_2SO_4).	Hardness (in terms of $CaCO_3$).			*Fatty Matter.
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Total.	Filtrate.			Total.	Permanent.	Temporary.	
Thick suds	2858·6	972·8	251·8	1885·8	1334·6	1·05	11·33	31·30	119·0	59·3	927·5		5·6	0·0	5·6	810·3
Thick suds	2055·6	795·2	162·8	1260·4	911·2	2·32	8·97	25·38	120·6	54·0	832·1	...	...	...	...	707·7
Mixed washing-off and neutralising waters	198·8	56·0	5·5	142·8	134·8	0·20	1·07	2·99	8·9	2·1	31·8	...	9·1	1·3	7·8	31·5
Mixed washing-off and neutralising waters	478·0	178·6	23·2	299·4	232·8	0·72	2·43	7·05	26·1	11·3	148·4	...	...	...	...	142·2
Washing-off water after milling	292·1	164·5	14·9	127·6	69·6	0·09	4·40	11·15	29·3	18·8	53·0	...	...	...		119·1
First washings from carbonising*	344·9	80·3	2·0	264·6	85·2	0·51	2·07	6·11	7·7	2·1	...	160·7	236·0	236·0	0·0	...
First discharge from neutralising	2030·8	117·2	21·7	1913·6	1847·8	0·32	4·64	20·44	16·0	5·0	551·2	...	6·3	2·7	3·6	4·8
Final effluent	438·4	2·0	0·9	436·4	351·0	0·19	0·31	0·97	3·8	3·8	...	61·7	172·0	102·0	70·0	...
Final effluent	474·0	0·4	0·3	473·6	342·4	0·23	0·31	0·64	4·2	4·2	...	107·8	306·4	248·2	58·2	...

* Coarse fibres, weighing 33·67 parts per 100,000, were sieved out before analysis.

clean water in washing machines. This is the process adopted at Providence Mills, Earlsheaton, where Messrs W. Greenwood and Sons carry on the business of rug and blanket manufacturers, and liquid refuse is produced in the processes of dyeing and scouring. Here Messrs C. H. Marriott, Son & Shaw, Civil Engineers, Dewsbury, have constructed settling tanks and filters for the scouring refuse. The dyewaters are discharged into the sewer.

The raw materials used in the mill are wool and shoddy, and to these oil is added before they are spun into yarn. After the goods have been woven they are scoured with fuller's earth to remove dirt and grease. The dirty water from this scouring process amounts to 25,000 gallons a day, and as some of the wool used has not been previously scoured, but contains its natural grease and dirt, and as something like 2 tons of fuller's earth are used every week, it can be readily understood that the crude refuse contains a large amount of polluting matter.

A ground-plan of the purification works is given in Fig. 37. The refuse is discharged from the mill through a small screening chamber, where alumino-ferric is added as a precipitant, and runs by gravitation into six settling tanks arranged in a special manner. They are provided with a central distributing channel from which the liquid can be led into any one of the six tanks. Each of the tanks is provided with an outlet into a drain which conveys the tank effluent to the filters. The inlets and outlets, as will be seen by referring to the block-plan, are so arranged that the refuse can be first turned into any one of the tanks and from it led through all the others successively. By this arrangement the refuse can be treated through the whole of the tanks, from number one to number six consecutively, until number one requires cleaning, when it can be put out of use without interfering with the remaining five; and again when number one has been cleaned and brought into use number two can be put out of use and the refuse discharged through the remaining five in series, and so for the others.

Each tank is 20 feet by 14 feet by 6 feet in depth, and holds 10,000 gallons. There is a baffling wall across each, 5 feet from the inlet end, and at the bottom of this there are openings 12 inches high through which the liquid is made to pass. To keep back floating grease, a scum-board is provided 3½ feet from the outlet end, which dips into the liquid some 4 inches. A valve is provided at a depth of 3 feet from the surface of the liquid, and through this the top water is discharged when the tank is cleaned. A sludge valve is provided at the bottom, the floor being dished towards it to enable the tank to be readily cleaned.

This arrangement of the tanks has several advantages. By always turning the refuse first into that tank which is next to be cleansed a stiffer sludge is obtained, and this is of special advantage in the case of a sludge containing much fuller's earth and grease, as in such a case the sludge is invariably very retentive of water. The last tank in the series is always the cleanest and thus available for catching any suspended matters which may have escaped from the others. In cleansing the tanks only one-sixth of the total amount of tank room need be out of use at one time. The repeated baffling walls and scumboards are also an advantage.

One objection to these tanks is that the baffling walls reach down too near to the bottom of the tanks and the current is deflected so far downwards that it appears to stir up and carry along with it some of the solids which have been deposited.

For dealing with the effluent from the settling tanks there are two filters each 30 feet by 15 feet and 4 feet in depth of material. They are filled with broken stone covered with screened clinker varying in size from 2-inch material at the bottom to ½-inch at the top, and are under-drained with special tiles. The filter effluent is discharged into a large reservoir which receives also roof water and a little surface water from the adjoining field in time of rain.

TABLE LVIII.

SAMPLES TAKEN AT PROVIDENCE MILLS, EARLSHEATON (W. GREENWOOD & SONS).

(*Results expressed in parts per 100,000.*)

Average of Several Samples of	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total.	Ash	Ammoniacal.	Albuminoid (Wanklyn)	Organic (Kjeldahl).	Total.	In Solution.	Total.	Permt.	Tempy
Crude refuse	906·1	802·7	462·0	103·4	76·4	1·16	4·96	9·96	25·64	2·09	86·1	49·7	**36·4**
Tank effluent	65·5	1·3	1·2	64·2	50·2	0·70	0·12	0·42	1·27	1·18	32·6	30·9	**1·7**
Final effluent	97·3	1·9	1·5	95·4	75·1	0·67	0·10	0·32	0·77	0·74	62·1	49·4	**12·7**

There are three sludge filters, each 20 feet by 17 feet, and constructed like the effluent filters, but with only 18 inches depth of medium. These are also under-drained to the reservoir. After the sludge has dried to some extent upon the sludge filters it is barrowed on to the adjoining field.

As has been mentioned, it is characteristic of sludge containing fuller's earth and grease to retain an excessive amount of moisture, and the arrangements for dealing with the sludge have here been found quite insufficient. In five weeks' working it was found that nearly 60 cubic yards of wet sludge accumulated on the filters, and this only dried to a very slight extent after lying there for two weeks. Fortunately part of the field adjoining the settling tanks lies much lower, and the sludge is now run by gravitation into a corner of the field.

In this case probably the best way of dealing with the sludge would be that described on p. 263, namely, to run it into trenches, which should be covered up with soil as soon as possible. At another mill in Yorkshire where similar refuse is dealt with it has been found necessary to install sludge presses, the sludge cake from which is used for filling up hollows in the land and some of it for manure; but the pressing of the sludge costs about 2s. per ton of sludge cake produced.

The results of the above treatment of the trade refuse have been very satisfactory. Analyses of the crude and treated refuse and of the sludge produced will be found in Tables LVIII. and LIX. Before these works were installed the water supply for the mill was, with the exception of a little roof and surface water during wet weather, taken from the town's mains. For the last six months the effluent from the purification works has been pumped from the reservoir to be used, mixed with town's water, both for the manufacturing processes and for the generation of steam. Messrs Greenwood have found the effluent fairly satisfactory for dyeing, scouring, and boiler use, and have thus been enabled to reduce their bill for town's water by some £120 per annum.

TABLE LIX.

SLUDGES TAKEN AT PROVIDENCE MILLS, EARLSHEATON (W. GREENWOOD & SONS).

(*Results expressed in parts per cent.*)

Average of Two Samples of	Moist Sludge.			Dry Solids.*			
	Moisture.	Organic and Volatile Matter.	Ash	Organic and Volatile Matter.	Ash.	Nitrogen (Kjeldahl).	Total Fatty Matters.
Sludge from sludge filter . . .	89·18	3·95	6·86	36·54	63·46	1·03	21·71
Air-dried sludge .	66·26	12·68	21·05	37·62	62·38	1·01	18·32

* The figures are calculated from an analysis of the moist sludge.

The cost of the purification works was £800, including the cost of a pump for raising the effluent to the cistern which supplies the mill. The cost of labour, including general attention to the works and dealing with the sludge, is estimated at 15s. per week. The amount of alumino-ferric used as a precipitant is only small—a ton, which costs £2, 17s. 6d., lasting for eighteen weeks.

The total cost therefore, per annum, is as follows:—

Purification works	Depreciation and interest on capital (10 per cent. on £800)	£80	0	0
Labour and general attendance		39	0	0
Precipitant		8	6	10
Total . .		£127	6	10

This would give a cost of just over 4d. per 1000 gallons treated, but, as has been stated, this cost is nearly wiped out by the saving effected in the bill for town's water.

Summary.—On examining the methods for the purification of waste waters from the various branches of the textile trades, described in the preceding pages, it will be noticed that in many cases the purification process may be profitable, or at least that its cost may be to a great extent counterbalanced by the value of bye-products recovered.

At mills where the whole of the refuse consists of soapy waters the grease recovered will go far towards paying the whole cost, and in favourable circumstances will even yield a handsome profit (p. 179): at bleach crofts the worst of the refuse can be treated separately so as to give a return which will at least pay for that part of the purification process (p. 100): in wool suds it has been shown that large amounts of valuable substances are present, which can be recovered at a cost which more than recoups the manufacturer for the necessary operations, and which if run to waste enormously increase the cost and trouble of purification (pp. 114 and 117): and it has been pointed out that even in dealing with dyewaters the manufacturer may at least partially recoup himself for the expense of purification (p. 138).

It is very often found that waste waters of very different kinds are discharged from the same premises, as, for instance, piece scouring and dyeing refuse from the premises of a woollen manufacturer, or bleaching and printing refuse from the premises of a calico printer; or, again, that although the refuse may be from one trade process, it may vary greatly in its polluting character, according to its immediate source, like the kier liquor compared to the other waste waters of a bleach croft; and in some cases, for example where there is piece scouring, the treatment of one part of the discharge may be profitable. In such cases it will generally be much more economical to deal separately with the liquids more difficult or profitable to treat, and to purify the resulting effluents along with the rest of the refuse from the mill (see pp. 100 and 184).

At the other extreme as regards impurity come the washing-off waters, which form the final discharge from practically every trade process, and it is often claimed that they are pure enough to be discharged to a stream without treatment. It must be admitted that if carefully separated from other refuse they may be so, but there are many objections to their direct discharge. In the first place, the purer waters are discharged from the same machines and vats as the fouler liquids, and two sets of drains would be necessary if the former were to be discharged to the stream and the latter to purification works; in the second place, the necessary attention to the valves for turning the liquids in the one direction or the other cannot or will not be given by the man in charge of the machines or vats; and, in the third place, the fouler liquids are usually more difficult to purify efficiently without dilution by the less polluted. It will often, however, be advantageous for a manufacturer to catch his cleaner waste waters by a separate system of drains, either for direct re-use, or for separate purification so that they may be re-used; but if this is not done, it is generally preferable, from the point of view both of the manufacturer and the Rivers Authority, first to recover any valuable bye-products and to treat in a preliminary way any refuse which may be specially intractable, and then to mix the effluent from this process with the rest of the waste waters, including washing-off waters, for treatment in one set of purification works.

From the foregoing descriptions of works and a study of the special apparatus described in Chapter XI., a suitable method of dealing with the waste waters produced in any branch of the textile trades can be easily selected. Where fibrous matter is present in the refuse it is always better to remove it by screening before attempting further purification, for when thus recovered it generally more than pays for the cost of recovery, whereas if allowed to remain it greatly increases the volume of sludge, or it passes on to choke filters. In dealing with such varying liquids it is advisable that an averaging tank should be provided, where all the various discharges become thoroughly mingled, or, where it is necessary to pump, a large sump serves the same purpose. This mixture often has the effect of producing a precipitation of the solids, and even where this is not the case it renders more regular and certain the action of any chemical precipitant which may be added (pp. 140 and 153). Settling tanks are almost always necessary, and their form and arrangement must be determined after consideration of the available site and its surroundings, and especially after deciding whether it is necessary or advantageous to resort to pumping. The use and choice of a precipitant should in all cases be settled only after careful tests, and the method of its application requires equal care. For determining the subsequent treatment of the refuse, the first consideration, as has already been suggested, is the presence or absence of organic matters derived from the raw materials, or in some few cases from the substances used in the processes of manufacture: when these are present some biological method may have to be adopted as the final part of the treatment, such as has been recommended in the case of wool-washing and silk-boiling refuse: when they are absent, as, for example, in the waste waters from a dyehouse, a simple straining of the tank effluent is likely to suffice.

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CHAPTER X.

MISCELLANEOUS TRADES.

Galvanising, tinplating, and wiredrawing—The moist copper process—Drainage from shale heaps—Manufacture of copperas and alum—Alkali manufacture—Soap making—Grease extraction—Grease distillation—Oil in condensing water—Tar distillation—Mineral-oil refining—Tar spraying of roads—Glue, size, and gelatine manufacture—Slaughtering of animals, bone boiling, tripe dressing, trotter boiling, tallow and dripping preparation—Dairy and creamery refuse—Laundries—Sheep washing—Sheep dipping—Stone sawing—Sand washing—Ore washing—China-clay washing and grading—Gee's centrifugal machine—Mineral-water manufacture, clay mixing, flint grinding, file scouring, and cutlery grinding—Varnish and paint manufacture—Beet-sugar manufacture, sugar refining, and starch manufacture—Working of salt deposits—Conclusion—Bibliography.

Galvanising.—The object of galvanising is to coat the surface of iron with a thin layer of zinc, which protects the metal underneath from oxidation. The iron is sometimes first annealed to render it soft, and is then pickled in hydrochloric or sulphuric acid to dissolve or loosen the scale of oxide which rapidly forms on any exposed iron, so as to leave a clean surface to receive the coating of zinc. The acid employed in the process is usually diluted with water till it has a strength of 12 to 15 per cent., although lower and higher strengths are used, and when it will no longer "bite"—that is, when it will not act quickly enough upon the oxide of iron—it is discharged as "waste pickle." The acid is generally used cold, although its effect would be greater if it were warm. The pickled iron is thoroughly washed and sometimes rubbed with sand and then dipped into a bath of molten zinc, to which some flux, such as ammonium chloride, is added.

It will thus be seen that the sources from which waste liquids arise are the pickling and the washing processes. The waste pickle from the pickle tank (see Table LX.) is a muddy liquid containing large amounts of oxide of iron in suspension, and in solution large amounts either of chloride or sulphate of iron, and sometimes as much as 5 per cent. of free acid. The wash waters are of a similar nature, but more dilute.

These liquids, if discharged to a stream, cause, like the ochre waters mentioned in Chapter II., a reddish-brown deposit in the bed of the stream, and, largely owing to their acidity, render the water incapable of supporting animal and vegetable life, or of being used for industrial purposes. The injury that has been caused through such liquids being discharged into streams has been very serious, and is graphically described by the

1868 Commission in their Fifth Report (p. 34) in regard to the rivers of South Wales, and this state of matters remains still to a great extent unaltered, in spite of the fact, pointed out by the Commissioners, that the pollution is quite preventible.

In the first place, much acid is wasted either by discharging the contents of the pickle tanks too early or by using the acid cold, and the quantity of washing water can be much reduced by using a tank of water into which to dip the goods when they are removed from the pickle tank. This water, when charged with acid, may be used to dilute the acid in the pickle tank when that is made up afresh. By attention to these matters the quantity of waste liquids can be greatly reduced. In the second place, the acid which escapes in the waste pickle can be recovered and re-used, and the iron it contains can be separated from the sulphuric acid pickle in the form of copperas or ferrous sulphate, and from the hydrochloric acid pickle as oxide of iron, both of which have a commercial value.

In order to recover copperas, the spent sulphuric acid pickle is run into a lead-lined tank containing scrap iron to neutralise the excess of acid, and is there evaporated by means of steam coils ; and the concentrated liquid after settlement is run into other lead-lined tanks, where, on cooling, copperas crystallises out. If scrap iron is not used to neutralise the acid, the latter becomes concentrated during the evaporation, and in that case the mother liquor, after the removal of the copperas, can be returned to the pickle tank.

For the utilisation of waste pickle containing hydrochloric acid, Professor Turner has patented a process (No. 16,166, 1888) in which the spent pickle is heated in a reverberatory furnace, with the result that hydrochloric acid is liberated and oxide of iron is left behind. The liberated acid is condensed and re-used, whilst the oxide of iron is sold to be made into paint. This process has been adopted at the works of Messrs Walker Bros., Walsall, who purchased the patent rights, and is said to produce a profit.

Another method of utilising waste pickle is as a precipitant in the clarification of sewage or other waste liquids, and in some cases the waste pickle is carted to the sewage works for this purpose. Generally, however, it is preferable to admit the refuse gradually into the sewers, and to add lime at the sewage works to neutralise the acidity and to precipitate hydrate of iron, which then carries down organic matters from the sewage.

If one of the above processes is not adopted, and it is necessary to render this kind of waste fit to discharge to a stream, a sufficient quantity of lime must be added to neutralise the acidity, together with a further quantity sufficient to precipitate the iron present in the solution, and settling tanks must be provided for the deposition of the sludge thus produced. With a sulphuric acid pickle the deposit consists of oxide of iron mixed with sulphate of calcium, and has little or no value, whereas the deposit from a hydrochloric acid pickle consists almost entirely of oxide of iron, which can be made into paint. As the sludge produced is large in quantity in comparison with the amount of refuse, the settling tanks should be of considerable size, at least capable of holding two days' flow, and subdivided to allow of frequent and regular cleaning, and for the same reason a large area of sludge filters is necessary.

Even if the discharge of waste pickle is prevented, as previously suggested, the washing waters cannot be considered fit to be discharged to a stream, and may have to be purified by lime precipitation in the manner just described, but as they contain comparatively little acid and iron their purification is much easier and less expensive.

After treatment of this kind the tank effluent will be an exceedingly hard liquid, and in some cases it may have to be softened to prevent injury to users of the stream lower down.

Tinplating.—In the manufacture of tinplate the processes are essentially the same as those described under galvanising, except that a bath of molten tin is used instead of zinc. In galvanising, hydrochloric acid is more often employed as the pickle, whereas in tinplating the use of sulphuric acid is more common, although either may be used. The waste liquids can be dealt with as described above.

Wiredrawing.—In wiredrawing, the iron or steel rods as they come from the rolling mills are reduced in diameter by drawing them through successively finer holes in steel blocks. Before being drawn, however, the coils of wire are cleansed by being dipped into a pickle of hydrochloric or sulphuric acid, exactly as in galvanising, or, in the case of very fine wire, into stale beer, which acts as a pickle on account of the organic acids it contains. On being removed from the pickle the coils are rinsed with water and dipped into a tank containing milk of lime to remove the last traces of acid and to check oxidation.

It will thus be seen that in wiredrawing, besides similar discharges to those produced in the operations of galvanising and tinplating, there is an escape of milk of lime from the coils of wire as they are removed from the liming tank.

In the treatment of the refuse from wiredrawing care should be taken to deal with the spent pickle separately by one of the methods suggested above, when the washings of the pickled wire and the discharges from the liming operation can be passed together into settling tanks, where the lime will precipitate any iron in solution.

Where stale beer is used for pickling, the spent pickle is of a grossly polluting character. If, as is usual, it forms only a small proportion of the refuse discharged, it may be mixed with the rest and treated in the same way. If, on the contrary, it is present in considerable proportion, this treatment will not be sufficient, and recourse must be had to some biological method of purification, such as has already been suggested for the treatment of brewery refuse (see p. 63). Analyses of the various discharges from wiredrawing are given in Table LX.

The Moist Copper Process.—There is another source from which waste iron liquids are discharged. In the production of copper from copper pyrites, by what is known as the moist process, the copper ore is roasted for the recovery of the sulphur, and is then again roasted with common salt to bring the copper into the form of a chloride. This, with any sulphate present, is dissolved out in water, and the copper displaced from solution by means of scrap iron, and when this displacement is complete the iron liquor is discharged as refuse. Such a liquor contains large amounts of iron in solution, in one case 300 parts per 100,000 were found, but differs from the other waste iron liquids described in that it contains no free acid. The iron can be removed by precipitation with lime in the same way as has been proposed for dealing with the refuse from galvanising.

TABLE LX.

REFUSE FROM WIREDRAWING WORKS.

(*Results expressed in parts per 100,000.*)

Nature of Sample.	Total. Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Alkalinity (in terms of CaO).	Acidity (in terms of HCl).	Iron.	
		Total.	Ash.	Total.	Ash.				Total.	In Solution.
Waste pickle . .	19058·0	18·0	12·4	19040·0	6420·0	999·0	..	551·1	7000·0	7000·0
Waste pickle after settlement . .	752·2	18·2	14·0	734·0	486·0	17·4	..	..	118·2	..
Do. . .	668·2	1·2	1·2	667·0	454·0	9·3	..	45·2	158·8	..
Sediment in waste pickle . . .	3535·0	1615·0	1250·0	1920·0	1210·0	203·0	..	..	1528·8	540·4
Brewery refuse after use at wire works .	14210·0	1148·0	358·8	13062·0	9860·0	935·0	..	*1080·0	4089·4	3955·0
Final washings of wire	91·0	31·0	26·5	60·0	57·0	0·6	19·0	..	8·7	..

* Acidity expressed in terms of lactic acid.

Drainage from Shale Heaps—*Copperas Manufacture.*—In the direct manufacture of copperas, a process is employed very similar to that suggested above for dealing with spent sulphuric acid pickle. The copperas is made by dissolving scrap iron, and especially the waste wire from wire works, in strong sulphuric acid, and afterwards evaporating the solution for the recovery of the crystals of sulphate of iron. From this process there should be no liquid refuse except, it may be, from washing floors and vats. Another process, described in the Third Report of the Rivers Pollution Commission, 1865, vol. 2, Q. 1926, is still in use, and may cause great pollution of streams. Shale containing large quantities of pyrites is piled in a heap, sometimes half an acre or more in extent, and 5 or 6 feet in depth, and exposed to the air and the rain. Ferrous sulphate and sulphuric acid are produced from the pyrites by oxidation, as has already been explained in describing the production of ochre water in a mine (see p. 9), and are dissolved out by the rain, or in dry weather by sprinkling the heap with water. The liquids draining from the heap are caught in a well and pumped back to percolate again through the shale until by this circulation they become sufficiently saturated with the ferrous sulphate. The strong acid solution is then treated with scrap iron to neutralise the excess of acid and evaporated in lead-lined pans for the recovery of the copperas. So long, therefore, as the process is in complete operation there should be no liquid refuse discharged; but the heap of shale in course of time becomes more or less exhausted of its sulphur, when the liquid draining from it is so weak that its evaporation is not profitable and the shale is abandoned as useless. The oxidation of the pyrites still continues, and the water draining from such a heap in wet weather, although not containing so much ferrous sulphate as to pay for evaporation, will for many years continue to be of a very polluting character. In one case, where such a heap had been left derelict for over five years, samples of the water draining from it were found to contain 4 per cent. of iron and 2 per cent. of free sulphuric acid.

Alum Manufacture.—A somewhat similar acid discharge is produced in works where alum is manufactured from shale. In this process the shale is boiled with sulphuric acid, and the acid liquor, with or without the addition of the salt of an alkali, is evaporated down until the alum salt crystallises out. The spent shale which has been thus treated is usually thrown on a waste heap exposed to the weather, and the rain washes out from it considerable quantities of acid. In one such case the water draining from a heap of spent shale contained 845 parts per 100,000 of free sulphuric acid.

Only one method can be suggested for dealing with waste acid liquids such as the above. They should be drained into a tank and neutralised with lime, and unfortunately these spent shale heaps continue to yield acid discharges for a long time, so that the treatment becomes somewhat expensive. If a spent heap contains enough carbonaceous matter to make it combustible, it may be disposed of as fuel.

Alkali Manufacture.—A somewhat similar source of pollution, but one which gives rise to a much more objectionable kind of refuse, is found in connection with the manufacture of carbonate of soda by the Leblanc process. The carbonate of soda is produced from common salt by heating the salt with sulphuric acid to drive off the hydrochloric acid and to produce sulphate of soda or "salt cake." This is then roasted with small coal and limestone to produce "black ash," which is a crude mixture of carbonate of soda, sulphides, polysulphides, hydrate and carbonate of calcium, together with unused carbonaceous matter. This black ash is lixiviated with tepid water, to extract the carbonate of soda, and the mass remaining is thrown upon a spoil heap. Such a spoil heap may reach great dimensions and, being exposed to rain and the carbon dioxide of the air, yields up its sulphides, which escape in the drainage waters. These cause great pollution of any stream into which they may be discharged, and especially when they come into contact with any acid liquid, which immediately liberates sulphuretted hydrogen with its offensive smell. They also form an objectionable incrustation on the banks and bed of the stream. Table LXI., quoted from Mr Naylor's book on *Trades' Waste* (p. 244), gives an analysis of this incrustation, together with analyses of the fresh waste and the drainage from a waste heap.

Fortunately, the prevention of such a discharge is a profitable operation, as the sulphur the waste contains can be recovered either in the solid form or as sulphuric acid. The best known method of recovery is that of A. M. Chance, in which the waste is treated with carbon dioxide, made by heating limestone in kilns, and the sulphuretted hydrogen thus liberated is burnt either to sulphur dioxide by giving a sufficient supply of air, or to sulphur by giving a limited supply of air in presence of heated ferric oxide. This process is especially applicable to the fresh waste, but can also be applied to the liquid draining from an old heap; but, as with spent shale heaps, the old black ash waste will continue for many years to yield polluting drainage waters, which gradually become more dilute until the sulphur they contain does not pay for recovery.

TABLE LXI.

ALKALI WASTE AND DRAINAGE.

(*Results expressed as percentages.*)

	Alkali Waste.	Incrustation.	Drainage.
Total sulphur	10·50	2·90	0·268
Sulphur as sulphate	9·67	1·87	0·036
Sulphur as sulphide	0·01	0·07	0·078
Oxidisable sulphur (by difference)	0·83	1·03	0·232
Carbonic acid	7·99	16·50	none
Coke	5·07	1·82	none
Siliceous matter	13·82	10·86	0·002
Oxide of iron and alumina	1·20	0·77	0·006
Lime	21·28	22·90	0·300
Magnesia	0·23	0·54	trace

Fortunately, also, the Leblanc process is not now that most commonly used for the preparation of carbonate of soda, as the Solvay ammonia-soda process, in which the alkali is produced by passing ammonia gas together with carbon dioxide into a strong brine, has to a great extent taken its place. The only refuse from this process is the mother liquor, containing chloride of calcium, from which the ammonia has been distilled. This is usually run on to waste ground, where the lime salts are deposited after the evaporation or percolation of some of the liquid. The water draining from such a deposit is exceedingly hard and may be injurious to a stream in that respect, but it is not offensive like the refuse from the Leblanc process. Recently this waste chloride of calcium liquor has been brought into use for the prevention of dust on roads.

Another still more modern process of manufacture is the best from the point of view of rivers pollution, for it produces no waste waters. In it the alkali is prepared by electrolysing brine, when chlorine is given off at one pole and caustic soda is produced at the other.

Soap Making.—Curd soap is made by boiling up an oil or fat with an aqueous solution of caustic soda, when the fatty acids of the oil combine with the soda to form a soap, leaving a solution of glycerine in the water present. By the addition of large quantities of common salt either in the solid state or as strong brine, the soap is then separated in the form of a curd, and from this the "spent lye" is drained off. This liquid at the time of the 1868 Commission (First Report, p. 103) was discharged as refuse, but the Commission pointed out that it contained large amounts of glycerine, for which there was an increasing demand, and that the glycerine could easily be recovered from the spent lye by concentration and distillation. This recovery of glycerine has now become the most profitable part of the soap-maker's trade, but as a rule, at least in the smaller soap works, the crude spent lye is sold to a chemical manufacturer. In such a case the discharges from the manufacture of curd soap should be confined to dirty waters which have been used for washing floors and utensils, and these are only small in amount.

In the manufacture of soft soap caustic potash is boiled up with an oil or fat, and the resulting product forms the soap, so that there is no spent lye to be disposed of, and the only waste waters are those from washing, which can easily be purified by precipitation with lime in settling tanks and straining through fine cinder filters.

One process commonly in use at soap works may give rise to polluting discharges. This is the causticising of the carbonates of the alkalies with lime in the manner described on p. 88. From this process there may be a discharge of spent lime, but, as previously shown, this can only occur through carelessness or mismanagement.

In the larger soap works the spent lye from the making of curd soap is concentrated and sometimes distilled for the extraction of the salt and the purification and recovery of the glycerine. The crude spent lye, which contains about 7 per cent. of glycerine and an equal amount of common salt, as well as albuminous, resinous, and soapy matters, is first slightly acidified with hydrochloric acid to separate any grease it contains.

It is then treated with an iron alum salt or alumino-ferric to precipitate albuminoid organic matters, which are removed by passing the mixture through a filter press. The acid filtrate is rendered slightly alkaline with caustic soda, which causes the deposition of further impurities, and these again are removed by filter pressing. The lye thus purified is concentrated in a multiple effect evaporator until most of the salt it contains crystallises out, and the glycerine present amounts to some 80 or 82 per cent. If a purer glycerine is required it is obtained by distilling the crude product in a vacuum still, by extracting it with a solvent, or by dialysis.

The waste waters produced by the evaporation process are the condensings (see Table LXII.) and the residue remaining after distillation, together with any water which has been dirtied in washing the floors and apparatus. The residue after distillation is best disposed of by placing it on the ash heap, while the other refuse can be purified either by application to land or by precipitation with lime and straining through cinder filters.

TABLE LXII.

RIVER WATER BEFORE AND AFTER USE FOR CONDENSATION OF DISTILLATE FROM CONCENTRATION OF SPENT LYE.

(*Results expressed in parts per 100,000.*)

	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Alkalinity (in terms of Na_2CO_3).	Hardness (in terms of $CaCO_3$).		
		Total	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl)	Total.	By Filtrate.		Total.	Permt.	Tempy.
Before use	42·3	2·1	1·9	40·2	26·6	0·60	0·08	0·31	0·68	0·60	15·9	19·3	10·9	8·4
After use .	227·4	13·0	7·6	214·4	203·2	0·58	0·09	0·31	1·19	0·93	200·3	3·9	1·1	2·8
Do. .	81·8	6·4	1·6	75·4	53·8	0·64	0·26	0·64	3·34	2·84	24·4	21·5	9·3	12·2

Grease Extraction.—In connection with the wool trade, in which, as has been explained, large quantities of greasy and soapy liquors are treated for the recovery of the fats they contain, a subsidiary branch of trade has arisen for dealing with these liquors and fats. The grease extractor generally provides and works seak plants, such as those described on pp. 112 and 175, at mills where wool-washing or piece-scouring suds are discharged, and removes to his own premises the puddings of magma or greasy sludge. These puddings are put into a steam-heated mechanical press and subjected to great pressure, sometimes as much as 2 tons to the square inch. By this means most of the water and oil are expressed, and these are received into a grease separator or large cask where the black oil separates from the water. The water is drawn off from the bottom of the cask and passed through one or more additional separators to intercept as much of the oil as possible. As it escapes it is still a very impure liquid (see Table LXIII.), highly acid in reaction and carrying with it appreciable amounts of oil in emulsion. The oil from the separators is partially purified by being heated up with somewhat dilute vitriol, and in some cases with oxidising agents, such as manganese dioxide or oil of mirbane, and is again settled to separate it from the acid liquid, which is run off as refuse.

Table LXIII.

REFUSE FROM GREASE EXTRACTION AND DISTILLATION.

(*Results expressed in parts per 100,000.*)

	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitric Nitrogen.	Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Acidity (as H_2SO_4).	Volatile Fatty Acids (as Butyric Acid).	Non-Volatile Fatty Acids (as Butyric Acid).	Total Fat.
		Total.	Ash.	Total.	Ash.						
Grease Extraction.											
Refuse from separation of grease . .	685·0	195·6	5·6	489·4	231·4	..	33·6	26·9	..	..	133·5
Refuse from separation of grease . .	621·7	39·3	6·1	582·4	288·4	..	41·3	..	..	..	..
Refuse from separation of grease . .	392·0	78·4	19·3	313 6	164·8	..	24·0	..	..	..	..
Refuse from purification of grease . .	7824·0	121·6	0·0	7702 4	560·0	..	66·3	6270·0	..	..	105·2
Refuse from separation of petrol . .	..	..	..	..	..	..	6 0	.	7·0	..	..
Grease Distillation.											
Crude refuse . .	109·3	17·9	3·0	91·4	51·0	..	9·7	..	37 6	12·3	..
Refuse after precipitation with bleaching powder . .	273·2	10·2	6·2	263·0	203·0	..	5·5	..	..	..	..
Refuse after precipitation with bleaching powder, settlement, and experimental filtration . . .	259·6	0·4	0·1	259·2	186·6	4·0	1·8	..	..	..	..
Refuse after settlement and straining	74·8	1·6	0·1	73·2	46·6	..	3·8	..	19 4	4·0	..
Refuse after settlement and straining	88·6	2·2	0·8	86·4	57·2	..	4·5	..	8·8	2·0	..
Refuse after settlement and straining	79·6	2·0	0·5	77·6	53·8	..	3·2	..	6·6	2·3	..

The grease extractor generally also buys from the cloth manufacturer the oily waste or shoddy, which is produced in the carding operation. This contains variable amounts of grease, sometimes as much as 25 or 30 per cent., and is treated in a steam press similarly to the magma puddings, the mixture of oil and water which escapes from the press being treated as described above. For this extraction of grease from shoddy waste an apparatus like that of the Industrial Waste Eliminators Ltd. (see p. 104) or Smith's Patent Vacuum Degreasing Machine (see p. 124) would seem to be very useful.

The liquid refuse escaping from these processes (see Table LXIII.) is fortunately not large in amount, and the quantity can often be reduced by using the acid liquid from the magma presses to moisten the shoddy before it is pressed. The treatment required by these acid liquids is that suggested for the purification of the effluents from seak tanks, namely, neutralisation with lime, settlement, and filtration.

The magma cake from the presses of the grease extractor is usually sold for making artificial manure. It still (see Table LXIV.) contains from 15 to 25 per cent. of grease, and this, besides being wasted, is actually detrimental to the use of the cake as a manure, since it makes it impervious to water, less easily broken down by weathering, and much more resistant to decomposition. Of late years, therefore, the grease extractor has brought into use a solvent process for recovering this grease, such as was suggested by the Royal Commission of 1865 in their Third Report (p. 34). The solvent used in the first instance was bisulphide of carbon, as suggested by the Commissioners, but this has now generally given place to petroleum naphtha. The magma cake, after being dried by exposure to the air, or in an apparatus like the Ruggles-Coles drier, is broken up and placed in a digestor having a capacity of 3 to 5 tons. The solvent is then pumped on to the top of the mass of cake and allowed to percolate through it, extracting grease in its passage, and the process is repeated two or three times: or heat is applied to the solvent

TABLE LXIV.

MAGMA AND PRESS CAKE FROM RECOVERY OF GREASE.

(*Results expressed in parts per cent.*)

	Wet.				Calculated on Dry Solids.			Percentage of Grease Pressed Out.
	Moisture.	Organic and Volatile Matter.	Mineral Matter	Grease.	Organic and Volatile Matter.	Mineral Matter.	Grease.	
Magma . .	40·02	54·39	5·59	42·62	90·68	9·32	71·05	84·30
Press cake .	11·43	68·74	19·83	24·64	77·61	22·39	27·81	
Magma . .	34·86	61·57	3·57	52·70	94·51	5·49	80·89	90·78
Press cake .	12·59	70·92	16·49	24·52	81·13	18·87	28·06	
Magma . .	58·04	37·69	4·27	24·54	89·83	10·17	58·48	70·20
Press cake .	22·02	65·28	12·70	23·06	83·71	16·29	29·57	
Magma . .	36·64	59·38	3·98	44·32	93·74	6·26	69·95	89·23
Press cake .	10·54	74·18	15·28	17·92	82·90	17·10	20·03	
Magma . .	38·83	57·48	3·69	41·12	93·97	6·03	67·22	75·83
Press cake .	10·14	77·32	12·54	29·77	86·04	13·96	33·13	
Magma . .	41·05	54·91	4·04	40·69	93·15	6·85	69·02	86·77
Press cake .	28·50	58·58	12·92	16·28	81·93	18·07	22·77	

in the digestor, and in the evaporation and condensation which results the solvent permeates the whole mass of cake, dissolving out the grease very thoroughly.

After the solvent has been drained off from the magma cake the remainder is driven off by live steam and condensed for re-use. The mixture of solvent and grease drained from the digestors is run into a still, where the solvent is distilled off, first by steam coils and finally with live steam, and is also condensed for re-use; while the crude grease is further purified by heating along with sulphuric acid, as described above. The magma cake by this treatment is to a great extent deprived of moisture and freed from grease, and, since it contains considerable amounts of nitrogen, forms an excellent basis for the manufacture of artificial manure. It will generally be found that the moisture remaining amounts to 10 per cent., and the grease to 5 or 10 per cent.

The only liquid refuse discharged from the above process, except the small amount of acid water separated from the grease, is the water condensed along with the solvent, from which it is separated by simple settlement. An analysis of this is given in Table LXIII. Even if great care is taken, there is danger that the solvent may escape along with the water, and it is therefore never safe to discharge this refuse into a sewer, where it might be the cause of a serious explosion. The amount of solvent thus gradually escaping is not inconsiderable, inasmuch as there is a loss of a gallon to a gallon and a half for every ton of cake treated, and much of this escapes along with the water, although by using a proper condensing apparatus for the solvent, such as that of Heinrich Schirm, Leipzig-Plagwitz, the loss may be reduced to 0·5 per cent. of the weight of cake treated.

The black oil recovered by the grease extractor is often used up again in the woollen mills, from the refuse of which it has been recovered, and in some cases the complete cycle of processes is brought into use by the manufacturer himself, who thus uses the same oil over and over again, and only buys sufficient to replace that which is unavoidably lost in the various operations. In the manufacture of woollen goods, when the piece-scouring suds and the shoddy from the carding are both treated for the recovery of grease, the amount recovered, without reckoning that extracted from the magma cake, has in several cases been found to reach over 70 per cent. of that originally used.

Grease Distillation.—A large proportion of the crude grease recovered by the grease extractor is sold by him to the oil refiner, who subjects it to a process of distillation. The products of distillation are (1) a small quantity of hydrocarbons, which are usually returned to the still with the next charge; (2) the bulk of the oils which, by cooling and pressing, are separated into a liquid oil mainly consisting of óleic acid and a solid which consists in great part of stearic acid; and (3) a residuum of liquid pitch. The mixture of liquid oils is chiefly used again in the wool trade; the stearic acid is sold to the candle maker, or for making polishes or currying leather; and the pitch is used for the insulation of electric cables or as a lubricant for heavy machinery, especially for the necks of rolling mills.

The only waste liquid from grease distilling comes from the final condenser, through which a spray of water passes in order to condense the gases which escape from the process of distillation. This water, being charged with the gases, becomes exceedingly offensive, having a strong smell of butyric acid and similar compounds. It also carries with it particles of grease, and if discharged to a stream may give rise to great nuisance, both because of its smell and because it coats the banks of the stream with greasy matter. Analyses are given in Table LXIII.

If this liquor is received into a tank of sufficient capacity to allow it to cool, the grease it contains rises to the surface and can be skimmed off and recovered. Even if the grease is thoroughly removed in this way, the water remains very offensive, and, having a high oxygen-absorbed figure, is still very unfit to be discharged to a stream. It can, however, be purified by precipitation with bleaching powder or some other oxidising agent, followed by settlement and treatment upon a percolating filter. In Table LXIII. the results of experimental precipitation and filtration of this kind are given, and it will be seen that the oxygen-absorbed figure has been reduced over 80 per cent. The effluent after this treatment was free from obnoxious smell.

The Discharge of Oil in Condensing Water.—In the exhaust steam from a steam engine, there are invariably small quantities of lubricating oil which the steam has carried with it from the cylinder. Where the condensed steam is discharged into a small stream, or where there are similar discharges from a number of mills in close proximity, the effect on the stream may be very marked, sometimes to the extent of producing a thick scum of grease over the whole surface of the water. There is also frequently an escape of grease from a mill where it has been carelessly used in lubricating the various parts of the engine and other machinery. These discharges of grease are for the most part due to carelessness, in the best mills with modern machinery, care is taken to trap all these greasy discharges and to recover the oil for re-use.

That which is carried by the steam can be prevented from escaping by interposing a trap such as the Princeps Oil Extractor of Princeps & Co., Sheffield (see Fig. 37A); the Empire Oil Separator of the Empire Engineering Co., Salford; or Brooke's Oil Separator of Holden and Brooke, Ltd., Manchester. These are contrived to extract the oil from the steam before it has become mixed with the condensing water. They all consist essentially of a cylinder or chest, through which the steam is passed, containing a large number of baffle plates upon which the steam impinges and to which the particles of oil adhere. These particles coalesce into globules which run down the baffle plates and collect in the bottom of the cylinder.

In the trap shown in the figure the baffle plates take the form of spirals, so as to offer as little obstruction as may be to the passage of the steam.

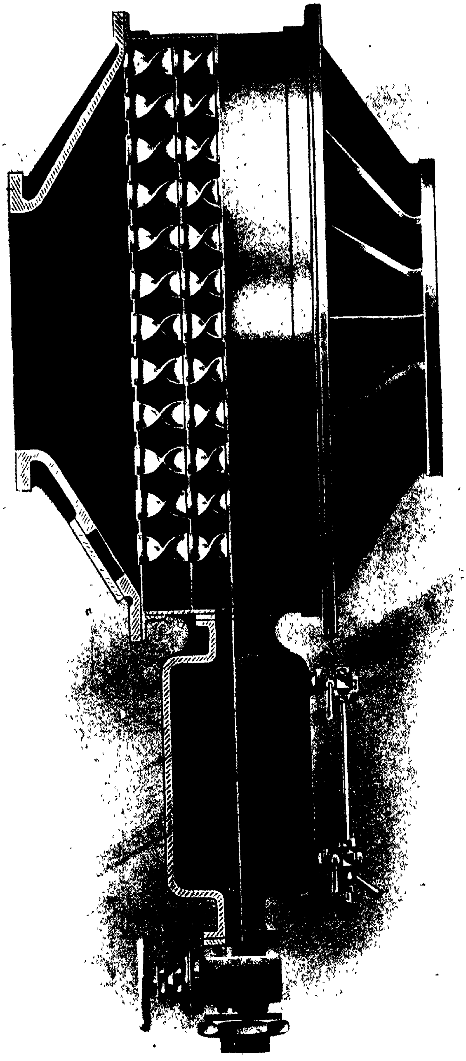

FIG. 37A.—Princeps Patent Oil Extractor and Steam Dryer.

In some cases the oil is removed after it has become mixed with the condensing water, when the treatment is totally different. If the condensing water is run into tanks or ponds of sufficient size to allow it to cool, the emulsified grease rises to the surface and can be retained by means of scumboards; or patent processes can be used, for instance, either chemical precipitation by means of lime and salts of alumina, in which case the grease is not recovered, or an electrical process, such as that of Davis Perrett Ltd., Westminster, in which by passing an electric current through the water, the grease is separated, and may be saved for re-use. One of these methods is usually employed where the condensing water is required again for steam raising. It is estimated that a layer of oil 0·01 inch thick offers as much resistance to the passage of heat as a 10-inch steel plate (Buchan, Memorandum on Steam Boilers).

Tar Distillation.—In the manipulation of tar for the purpose of separating it into its several constituents, and in purifying these, there are various discharges of waste water which are of a highly polluting character. These liquids are generally more or less dark brown and turbid and contain tarry matters, together with either acid or alkali which has been used in the processes.

In distilling tar the "first runnings" from the condenser contain ammoniacal liquor which is afterwards separated from the admixed naphtha to be distilled for the recovery of ammonia. As the tar distillation proceeds and the temperature rises the various oils coming from the condenser are collected in separate receivers and are known as light oil or "second runnings," carbolic oil, creosote oil, and anthracene oil, leaving a residue of pitch in the still. Towards the end of the distillation steam is forced through the tar, and this condenses along with the creosote and anthracene oils.

From this distillation of tar, therefore, it will be seen that there are two sources from which waste waters arise — the distillation of the ammoniacal liquor, yielding refuse the treatment of which has been fully dealt with in Chapter III., and the condensation of the steam passed through the tar in the still.

All tar works do not adopt the practice of collecting the various fractions of distillate noted above, but such may be regarded as a very complete process. The further purification and rectification of the various oils give rise to polluting liquids, but it will suffice here to deal only with those processes which are in more or less general use. Moreover, some of the fractions obtained as above are sold and used for various industrial purposes in this country without any further purification, for example, the creosote oil for the recovery of benzol from coke oven gases, and some are only partially purified and sent to Germany for use in the large colour works there.

The first runnings after the separation of the ammoniacal liquor, the light oil, and the carbolic oil, are washed with caustic soda, containing about 10 per cent. Na_2O, which dissolves out phenols and cresols, and these are again liberated as oils by passing carbon dioxide through the soda solution. This process yields a solution of sodium carbonate, which can be concentrated in an evaporator such as is described in Chapter XI., p. 275, and causticised for re-use, as described on p. 88, and this causticising process, if properly managed, does not give rise to any polluting discharge.

The oils, after treatment with caustic soda, are treated with dilute sulphuric acid (2 to 5 per cent.) to dissolve out pyridine and other basic tar oils, and are then washed with water and distilled and collected in various fractions. During this distillation process steam is passed into the still and condenses along with the oils, from which the water is afterwards separated and run to waste. The various fractions of oil thus obtained are treated with concentrated sulphuric acid to remove thiophene and other sulphur compounds, as well as unsaturated hydrocarbons. They are then washed with water and finally distilled with steam.

The acid solution containing the pyridine is used instead of sulphuric acid in the saturator of the sulphate of ammonia plant, when the ammonia liberates the pyridine, which is either skimmed off or condensed from the gases leaving the saturator. The acid washings are neutralised with soda, when the emulsified oil separates and is skimmed off, the neutralised liquid being discharged as waste.

There are thus at this stage the concentrated acid and washings to dispose of, and the condensed steam from the stills. When the acid is diluted with the washings, tarry matter separates and can be skimmed off, and the acid can then be used for dissolving out the pyridine, as above, or in the sulphate of ammonia plant.

It will thus have been gathered that there are numerous processes in which water is fouled, much of the refuse coming from distillation processes in which steam is blown through the still, but the bulk of it being spent gas liquor, or water which has been used for washing the various products. Each discharge of waste water is only small, but together they amount to a considerable volume, and must be treated before being allowed to reach a stream. For this purpose large settling tanks fitted with a series of scumboards should be provided. As the refuse cools, oily matters either sink or rise to the surface and are deposited in the tanks or retained behind the scumboards. The tank effluent, if treated with lime along with a salt of iron or aluminium, or with chlorine, which partly oxidises offensive gases and partly precipitates some of the dissolved matters, may be afterwards purified by means of a percolating filter (see pp. 64 and 269). Analyses of various discharges are contained in Table LXV.

Refining of Mineral Oil.—The working up of petroleum and shale oil differs very little from the processes adopted at tar works, and the refuse may be disposed of in the same manner.

Tar Spraying of Roads.—In recent attempts to prevent the dust nuisance on roads, tar spraying of the surface has come into very general use, and this has from time to time caused considerable pollution of streams, with resulting poisoning of fish. If the tarring is followed by a period of dry weather no harm generally results, as all the poisonous

TABLE LXV.

REFUSE FROM TAR-DISTILLING WORKS.

(Results expressed in parts per 100,000.)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Alkalinity (as Na_2CO_3).	Acidity (as H_2SO_4)	Hardness (in terms of $CaCO_3$).			Sulpho cyanides (in terms of Sulphur).
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn)	Organic (Kjeldahl).	Total.	Filtrate.			Total.	Permt.	Temp.	
Top water from creosote tanks	691·3	4·2	0·6	687·1	196·6	65·90	6·40	48·80	354·0	347·0	...	...	40·0	40·0	0·0	41·6
Washings after pyridine recovery . . .	1057·3	15·9	1·6	1041·4	654·6	1·00	0·98	3·13	199·0	182·2	...	22·0	239·0	151·4	87·6	...
Condensed steam used in benzol distillation .	402·0	2·1	1·8	399·9	188·3	5·48	0·74	7·06	104·2	96·0		...	186·5	169·0	17·5	...
Mixed refuse . . .	114·1	12·5	5·9	101·6	82·9	0·95	0·21	0·65	10·3	6·6	...	...	32·2	26·6	5·6	...
Mixed refuse . . .	187·7	10·8	6·7	176·9	142·3	6·95	0·47	5·31	42·3	37·9	...	...	51·5	50·0	1·5	3·3
Mixed refuse . . .	97·7	5·1	2·4	92·6	77·2	0·92	0·08	0·53	5·1	4·5	5·8	...	36·7	36·7	0·0	...

materials are absorbed; but if, soon after the tarring, there happens to be heavy rain, the soluble matters of the tar are washed out, and may cause great destruction of fish life in any stream which they reach.

The whole question has been very fully discussed by W. J. A. Butterfield, F.I.C., Assoc. Inst. C.E., in a paper given in *The Surveyor*, 1912, vol. 41, p. 277. He shows that the poisonous constituents of tar are the ammonia liquor and the tar oils and their associated bodies, and that it is easy to obtain tar suitable for spraying on roads, and freed from the bulk of these poisons by partial distillation or boiling. He suggests that it is safe to use a tar which

1. is of not lower specific gravity at 15° C. than 1·18;
2. contains not more than 1 per cent. of water or gas liquor, the ammonia in which is equal to not more than 5 grains per gallon of tar;
3. contains not more than 1 per cent. of light oils, and
4. contains not more than 3 per cent. by volume of crude tar acids.

Glue, Size, and Gelatine Manufacture.—The refuse which comes from the manufacture of glue, size, and gelatine is exceedingly polluting in character and may give rise to great nuisance. These products are extracted from animal tissues such as bone, skin, horn, and hoof by boiling with water, but from this extraction process there is no liquid refuse. In the preparation of the raw materials, on the other hand, and in the washing of utensils, considerable quantities of water are fouled, and as this carries with it large amounts of animal matter in solution and suspension, it is of a highly polluting character. For the description of the kind of refuse produced it may suffice to explain the processes adopted and to give analyses of the refuse in a particular instance.

In this case the raw materials are spetches from the tanyards, horns and bones. The spetches or waste bits of skin, including the ears and lips from the hides, come from the tanyard highly impregnated with the lime in which the skins have been soaked previous to dehairing (see p. 72). They are steeped in a tank containing weak hydrochloric acid to get rid of the lime. The horns and bones require the same treatment to extract the calcium phosphate they contain, and all the materials are washed in water to cleanse them of dirt. The cleansed materials are then boiled in vats with a sufficiency of water; the fats which separate are skimmed off, and after prolonged boiling the resulting liquor is run off and concentrated in vacuum pans sufficiently to set into the well-known cakes of glue, or into jelly-like size, on cooling. The residue from which the gelatinous matter has been extracted is dried and made into artificial manure.

In this case the manufacturer makes soap out of the fat recovered from his boiling pans, and as the quantity of hard soap made is not great, he does not trouble to recover glycerine from the spent lye, which is discharged as refuse.

TABLE LXVI.

WASTE WATERS FROM GLUE WORKS.

(Results expressed in parts per 100,000.)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Alkalinity (as Na_2CO_3).	Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Total.	Filtrate.		Total.	Permt.	Temp.
Crude refuse	1788·4	49·2	14·9	1739·2	1263·4	10·00	7·48	17·73	37·16	35·35	80·56	1105·0	1060·0	45·0
Precipitated refuse	1749·8	168·4	68·1	1581·4	1142·8	7·00	11·00	25·96	42·15	32·50	14·84	1150·0	986·0	164·0
Final effluent	523·1	28·5	13·6	494·6	371·2	10·23	3·58	9·40	3·43	2·84	61·48	250·0	228·6	21·4
Final effluent	891 2	72·8	3·5	818·4	779·4	...	...	..	16·40	...	...	...	...	...

From these premises, therefore, the trade refuse consists of water which has been used for washing the raw materials; the waste liquor from the extraction of lime from the spetches, which contains large quantities of chloride of calcium in solution; water which has been used for washing floors, vats, and casks; and occasional discharges of spent lye when soap is being made. The analyses of this refuse before and after treatment are given in Table LXVI.

Although the refuse is so grossly polluting in character, it is fortunately amenable to treatment, being readily purified by chemical precipitation and biological filtration. By chemical precipitation with lime and alumino-ferric the oxygen-absorbed figure was reduced from 22·4 to 14·5, showing a purification of 35 per cent., and this precipitated liquor, when applied to the experimental filter, described on p. 117, at the rate of 35 gallons per cube yard per day, yielded an effluent with an oxygen-absorbed figure of 1·7, showing a purification of 92 per cent. on the crude refuse. This effluent contained nitrates and did not putresce on keeping.

The refuse at the premises under consideration was for a long time treated by chemical precipitation and irrigation upon land, but, especially in summer, many complaints were made of the smells from the flooded land, which was indeed neither of sufficient area nor of suitable character. Since the above experiments a filter similar to that described on p. 271 has been provided in place of the land treatment, yielding results which are shown in Table LXVI. It will be seen that the tank effluent contained far more suspended solids than should have been allowed to reach the filter, but that notwithstanding this the reduction in the oxygen-absorbed figure is very marked.

Slaughtering of Animals, Bone Boiling, Tripe Dressing, Trotter Boiling, Tallow and Dripping Preparation.—From all these processes there is a discharge of dirty water very similar to that coming from the manufacture of glue and size, a liquid strongly impregnated with animal organic matter, and extremely liable to undergo offensive putrefaction (see Table LXVII.).

The blood obtained when animals are slaughtered should never be discharged along with the refuse waters, as it is valuable either as a food or as a manure. But even if care is taken to prevent the escape of any blood, the water used for swilling the slaughter house is highly polluting, and needs much the same treatment as strong domestic sewage to make it fit to be discharged into a stream. At large slaughter houses the recovery of grease from the refuse water is found to be profitable, and perhaps the simplest method in use is a Kremer apparatus such as will be found described in Dunbar's *Principles of Sewage Treatment* (p. 63), and can be seen in operation at the Withington Sewage Works of the Manchester Corporation.

Apart from the recovery of blood and fat, the liquid refuse from all these trades can be dealt with in the same way as has been suggested for the refuse from the manufacture of glue and size.

Dairy and Creamery Refuse.—The processes carried on at a dairy are somewhat variable, but may include separation of cream, butter making, cheese making, the Pasteurising of milk, and the preparation of casein and milk sugar. Since fresh milk is the raw material in all these processes, and since it is so liable to undergo fermentation, the necessity for keeping all utensils scrupulously clean will be obvious—indeed, the washing waters from floors, cans, centrifugal machines, and other apparatus form the bulk of the liquid refuse.

In many dairies the only operation is the separation of the cream from the milk, the former being sold and the latter being returned to farmers for feeding calves and pigs.

Where a cream separator is used the interior of the machine becomes coated with mucus, blood, and other impurities from the milk, but these substances should not be washed off and discharged with the rest of the liquid refuse. They should be scraped off and thrown upon the manure heap, or boiled up in food for pigs.

TABLE LXVII.

REFUSE FROM SLAUGHTERING OF ANIMALS, AND FROM BOILING OF TRIPE, COW-HEELS, AND TROTTERS.

(*Results expressed in parts per 100,000.*)

From	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Fatty Matter.	Coarse Solids (removed before analysis).
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Total.	Filtrate.		
Slaughter house (cleaning entrails) . .	4969·8	698·6	385·6	4271·2	3809·2	13·1	33·7	77·5	87·9	46·4	52·0	80·0
Slaughter house (killing cattle and sheep) .	2232·2	367·4	64·4	1864·8	519·6	42·6	82·0	192·0	198·0	148·5	89·6	243·0
Tripe boiling . . .	1061·6	369·6	12·4	692·0	64·4	4·4	38·6	109·7	59·6	52·0	145·8	nil
Trotter and cow-heel boiling	501·6	110·6	6·8	391·0	20·6	11·5	36·4	71·4	31·0	21·8	24·2	nil

In butter making the cream which has been separated from the fresh milk is churned to cause the fat globules to separate from the film of milk fluid with which they are surrounded, and to aggregate together. The skim milk is either sold as such or used for feeding calves, or for the preparation of cheese or casein, while the butter milk separated from the butter in the churn is used for feeding pigs. The butter is next washed with cold water, drained, salted, and prepared for market.

In cheese making the casein of fresh or skim milk is precipitated by rennet, and carries down with it most of the fat. The curd is washed, compressed, and ripened into cheese, while the whey is either fed to pigs or used in preparing milk sugar.

In the Pasteurising of milk the only refuse is derived from the washing of the vessels and apparatus which have been used in the process.

Casein is prepared from fresh milk or from skim milk by adding an acid to the diluted milk and collecting the precipitate thus formed. The liquid remaining is usually discharged as refuse, or it may be utilised in the same manner as the whey from cheese making.

Milk sugar or lactose is prepared by evaporating whey, clarifying the evaporated liquid with an aluminium salt, and further evaporating until the sugar crystallises out, leaving a mother liquor which is highly charged with organic matter.

The apparatus used in all the various processes must be kept thoroughly clean, and this is accomplished by washing with hot water to which a little soda has been added for the purpose of saponifying any fatty matter adhering to the vessels. Dairy refuse thus possesses the character of diluted milk, and is very liable to undergo acid fermentation and give off offensive odours from the butyric acid produced. If discharged into a small stream it gives rise to abnormal growths, which cause a great nuisance when they decay. The volume produced is estimated by Dr F. Guth (*Gesundheitsingenieur*, 4th March 1911) at 1 to 3 or more gallons for every gallon of milk treated at the dairy, and according to this author the composition of the refuse from the centrifugal machines and cheese making, and from the washing of milk cans, may be somewhat as follows:—

TABLE LXVIII.

DAIRY REFUSE.

(*Results expressed in parts per 100,000.*)

	Refuse from Washing of Milk Cans.	Mixed Refuse from Centrifugal Machines and from Cheese Making.
Oxygen absorbed from $\frac{N}{100}$ permanganate in ten minutes' boiling (Kubel)	9·3 to 45·6	15·4 to 101·9
Loss on ignition of total solids	33·1 to 71·2	49·2 to 273·3
Nitrogen (Kjeldahl)	2·4 to 5·1	5·8 to 11·8
Milk sugar	10·9 to 15·9	...
Fatty matter	15·9 to 20·9	...

Table LXIX. contains analyses of samples of refuse from a dairy where milk is Pasteurised, and also from a dairy where butter and cheese are made.

So long as the dairy is in connection with a farm there need be no difficulty in disposing of the refuse, as it can be distributed over the surface of grass land. At the Manor Farm, Garforth, in connection with the

TABLE LXIX.

DAIRY REFUSE.

(Results expressed in parts per 100,000.)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Acidity (as Lactic Acid).	Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Total.	By Filtrate.		Total.	Permt.	Temp.
Separated milk . . .	6288·0	...	...	...	*440·0	14·00	237·40	467·0	652·0	614·8	1224·0	...	...	...
Whey from cheese making .	6240·0	...	...	...	*476·0	28·80	70·56	133·0	470·4	466·0	468·0	272·5	272·5	0·0
Mixed refuse from butter and cheese making . . .	1338·3	79·3	22·1	1259·0	1126·8	1·34	2·72	8·5	35·5	24·9	46·8	91·4	72·9	18·5
Washing waters from Pasteurising	120·9	67·3	13·7	53·6	16·6	0·16	1·27	5·6	10·6	7·1	9·0	44·3	13·0	31·3
Washing waters from Pasteurising	166·9	83·4	4·4	83·5	19·9	0·14	2·09	5·9	19·4	11·7	27·0	56·8	16·9	39·9

* These figures represent the ash of the total solids.

University of Leeds, where on an average 50 or 60 gallons of milk are used daily for butter and cheese making, the refuse amounts to some 400 gallons per day. This is passed through a tank of 1200 gallons capacity, where it is mixed with the domestic sewage from the farmhouse, and the tank effluent is applied to half a rood of grass land, where it is absorbed.

Small dairies are, however, giving place to larger, in which the milk from several farms, amounting perhaps to 2000 or 3000 gallons daily, is dealt with, and the disposal of the refuse then becomes a problem which demands consideration.

Where a requisite area of suitable grass land is available the refuse is easily disposed of by irrigation, but probably not more than about 5000 gallons per acre of moderately strong refuse can be disposed of in this manner every day. According to Calmette (*Recherches*, vol. 7, p. 337) precipitation with lime or bleaching powder and settlement in tanks provided with scumboards, preliminary to the land treatment, diminishes the risk of nuisance. Treatment with bleaching powder or some other oxidising agent is specially to be recommended, as it destroys the butyric acid which is the chief cause of the offensive smell such refuse is liable to give off.

Experiments on the biological treatment of the refuse by means of septic tanks, followed by either contact beds or percolating filters, were undertaken at the Ballyrashane Creamery near Coleraine in 1902 under the direction of the Department of Agriculture and Technical Instruction for Ireland (see the Journal of this Department, March 1904, vol. 4, No. 3, p. 511). The septic tank was constructed large enough to hold nine or ten days' flow of the refuse, and was covered with tarred planks and 18 inches of soil, and each of the contact beds was sufficient to hold the daily flow, the first being filled with very coarse coke and the second with coarse gravel. In the septic tank the oxygen-absorbed figure of the refuse was reduced from 180 to 48 parts per 100,000, whilst the contact beds further reduced this figure to 13, a total reduction of over 92 per cent. No nuisance or odour of any kind was, it is said, produced from the works. The percolating filter was constructed of coke, but its effect was hampered by faulty distribution; it did not produce quite as good an effluent as the contact beds, but no attempt was made to remove the suspended matters contained in the effluent. The Department came to the conclusion that contact beds are preferable to percolating filters as being less liable to give off any odour; but with tanks of smaller size and the use of some oxidising agent the risk of nuisance from the percolating filters would certainly have been greatly reduced, if not obviated.

The effect of septic treatment has also been tried by Bowles (*Engineering Record*, 1911, vol. 64, p. 419), who finds that the lactic acid fermentation retards purification, but that by keeping the refuse in a septic tank for six days a purification of 50 to 60 per cent., judged on the organic matter, can be obtained.

Kattein and Schoofs (see *Milch Zeitung*, 1903, Nos. 7 and 8) have also studied the treatment of dairy refuse, and succeeded in treating it successfully at a rate over 50 gallons per cube yard of filtering material per day on a filter constructed of clinker somewhat like that described on p. 271, whilst Calmette (*Recherches*, vol. 5, p. 70) has designed works based upon experimental results and consisting of a septic tank and percolating filter to treat the refuse of a creamery dealing with 1000 gallons of milk daily.

In America attempts have been made by the Ohio State Board of Health and the United States Geological Survey (see Kimberley, *Engineering Record*, 1910, p. 50) to treat creamery refuse by settlement and filtration through sand, but the results have not been very satisfactory. The effluents obtained were putrescible, but this was due, according to Kimberley, to the high rate of filtration, although this was only 9 gallons per square yard per day.

In conclusion it may be stated that this kind of refuse can be disposed of by application to land, but that where the area is insufficient or the soil unsuitable biological methods can be employed, although a double filtration may be necessary in some cases.

Laundries.—It is questionable whether the refuse from laundries can legally be considered as trade waste water. Formerly it was the general custom for the dirty linen of a household to be washed on the premises, when the water fouled in the process could only be looked upon as forming part of the domestic sewage. The tendency of recent years is for regular traders to establish large laundries in country places near towns and to deal there with the dirty linen of the town dwellers. The washing of clothes, therefore, which ordinarily would be done by the inhabitants in their own homes is transferred to an entirely different district and concentrated in large establishments. In such cases the refuse discharged would undoubtedly appear to be trade waste water, but whether this is the legal view will have to be decided by the Courts. The question was discussed, but not decided, in the case of *Garfield* v. *The Yorkshire Laundries, Ltd.* (69 J.P. 411).

The process of washing clothes is too common to need any description. The refuse discharged from a laundry is a grossly polluting liquid, often stronger than an ordinary domestic sewage. It rapidly putrefies, and if discharged to a stream causes profuse offensive growths. In character it is almost exactly the same as piece-scouring refuse in the woollen trade, and it can be purified in the same way, either by chemical precipitation with lime, alumino-ferric, or calcium chloride, followed by filtration or application to land. As with piece-scouring refuse, if the volume of waste water is sufficiently large it may be economical to recover the grease.

Sheep Washing.—This is one of the oldest polluting trade processes and, it must be confessed, extremely difficult to deal with in a satisfactory way owing to the manner in which it is carried on. In most cases a pool is made upon a small stream, and into this the sheep are driven one by one, to be received by a shepherd standing in the water, who seizes each sheep by its head and back and moves it rapidly backwards and forwards in the water. This washing, aided by the potash salts present in the fleece, carries off large amounts of grease, dirt, soluble organic matters, and sometimes chemicals, such as carbolic acid and arsenic compounds, with which the sheep may have been previously dipped.

If the stream of water running through the pool is only a small one, as is usually the case, for sheep washing is done in dry weather in summer, the water which escapes from the pool may become very grossly polluted. The Royal Commission of 1868 (Third Report, p. 18) say of one sample that "it was an extremely filthy liquid, much stronger in its powers of pollution than ordinary water-closet sewage." Analyses of samples of a stream above and below a washing pool are given in Table LXX.

TABLE LXX.

WASTE WATER FROM SHEEP WASHING AND DIPPING.

(*Results expressed in parts per 100,000.*)

	Total Solids	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.)		Nitrogen.		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Total Fatty Matter.	Hardness (in terms of $CaCO_3$).		
		Total	Ash.	Total	Ash.	Ammoniacal.	Albuminoid (Wanklyn).			Total.	Permanent.	Temporary.
Sheep washing.												
Stream water above washing pool . .	25·6	0·5	0·5	25·1	15·1	.	..	0·18	..	13·9	8·1	5·8
Stream water below washing pool . .	41·6	10·3	5·0	31·3	23·3	..	.	2·06	..	15·2	6·3	8·9
Sheep dipping.												
Discharge from dipping tub	1089·0	303·0	66·4	786·0	448·0	10·0	7·3	121·80	256·0	..	..	..

It is obvious that no sheep washing should be allowed upon a stream the waters of which are used for household supply, and although in other cases the pollution of the stream may give rise to considerable injury, for instance, by killing fish, as a rule, seeing that the duration of the pollution is so short, and that it only occurs once or twice a year, there is no need to take special measures for its prevention. Where necessary it may sometimes be possible, while sheep washing is going on, temporarily to divert the stream below the washing pool on to a meadow.

Sheep Dipping.—This is a much more polluting process than sheep washing and occurs more frequently, as sheep may have to be dipped several times a year in order to meet the regulations of the Board of

Agriculture. Fortunately the discharges are small in amount and can easily be prevented from reaching a stream. Sheep dipping is done for the purpose of ridding the sheep of insect pests, and the chemicals in general use are lime and sulphur, carbolic acid and soap, tobacco and sulphur, and compounds of arsenic.

The dipping is generally done in an elongated wooden tub or cistern 500 or 600 gallons in capacity, large enough in its deepest part to hold a single sheep when floating in the liquid. The tub is filled with the dipping liquid and the sheep are passed through it one by one, each in turn being immersed by a shepherd standing alongside. As a hundred or more sheep may be passed through the same tub of liquid, to which fresh chemicals have been added from time to time, it can easily be imagined that the contents of the tub become grossly polluted. An analysis is given in Table LXX.

There is fortunately no necessity to let such a liquid escape to a stream; it can be stored up and strengthened for re-use, or if it finally becomes too foul, it is so small in quantity that it can easily be thrown upon the land at some distance from a stream. The discharge of even a small amount of a liquid such as this into a stream may have very deleterious effects; for instance, where carbolic acid has been used one result may be that all the fish in the stream are killed out. In fact, a sheep-dipping tub should never be allowed alongside a stream.

Stone Sawing.—In many parts of the country where quarries of sandstone are worked the stone is prepared for sale by being sawn into blocks or slabs. The quarried stone is firmly fixed in a frame under a set of parallel steel blades (sometimes as many as twelve), which are kept in motion backwards and forwards and gradually lowered so as to make a series of parallel cuts through the stone. To keep the saw blades cool a constant stream of water is directed into the cuts, and steel shot, carborundum, or sharp sand is used to assist in wearing a groove in the stone.

From stone sawing, therefore, there is a constant discharge of water carrying with it large quantities of fine sand or mud resulting from the sawing (see Table LXXI.). This waste water, if discharged to a stream, deposits its solids in the channel and makes the stream water very muddy. The discharge is fortunately never large in volume, and its purification or disposal is easy. In most cases the stone yard is in connection with a quarry, and it is often possible to run the waste water into the quarry, where the solids rapidly settle, and the water either percolates away or is sufficiently clarified to be pumped out with other waters drained from the quarry. Where this means of disposal is not available a series of settling tanks should be provided equal in capacity to the maximum daily flow of refuse, and in duplicate to allow of cleansing. Means should be provided for pumping or draining out the clear water after settlement of the solids when a tank is to be cleaned, and care should be taken to remove the deposited sand or mud to such a position that any water draining from it will not reach a stream. The amount of sludge produced from each frame may be roughly estimated at 10 to 20 tons per annum, and some of this can be ground up with ashes for the preparation of mortar. The clarified water can be used over again in the stone sawing, or is usually fit to discharge to a stream, although in some cases it may be necessary to pass it through a sand filter.

TABLE LXXI.

STONE-SAWING REFUSE.

(*Results expressed in parts per 100,000.*)

Nature of Sample.	Total Solids	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total	Ash.	Total.	By Filtrate.	Total.	Permt.	Tempy.
I. Crude .	1177·9	1072·3	1024·1	105·6	81·8	7·67	..	106·0	56·0	50·0
Settled . .	121·5	13·0	13·0	108·5	83·5	0·22	..	94·1	62·8	31·3
II. Crude .	7115·0	7095·6	6850·4	19·4	13·6	21·30	0·28	199·2	16·0	182·3
Settled .	53·1	35·9	34·9	17·2	11·8	0·08	0·04	11·2	8·6	2·6
III. Crude .	1295·4	1268·6	1196·8	26·8	22·0	7·58	0·16	29·7	14·4	15·3
Settled . .	49·8	2·2	1·8	47·6	37·4	0·10	0·10	29·0	18·9	10·1

The suspended solids in this class of refuse deposit very rapidly, as may be gathered from the results obtained by the quiescent settlement of the above three samples of stone-sawing refuse for varying periods which are given in Table LXXII.

TABLE LXXII.

RATE OF SETTLEMENT OF STONE-SAWING REFUSE.

Time of settlement (hours) . .	0	½	3	8	24	48
Sludge produced per cent. by volume	I. ...	5·60	3·45	3·00	3·00	3·00
	II. ...	...	44·50	35·75	28·50	28·00
	III. ...	4·65	3·85	3·80	3·75	3·65
Suspended matter remaining in effluent (parts per 100,000)	I. 1072·3	12·27	4·67	4·00	1·87	0·80
	II. 7095·6	...	9·20	3·20	1·20	1·40
	III. 1268·6	22·30	3·30	1·87	0·67	0·13

Where the suspended solids in the refuse are very fine their deposition may be assisted by the addition of a small quantity of lime, as has already been suggested in the case of coal-washing refuse containing clay.

Sand Washing.—Where sand filters are used for the purification of

Table LXXIII.

SAND-WASHING WATERS.

(Results expressed in parts per 100,000.)

Nature of Sample.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.			Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.		Hardness (in terms of $CaCO_3$).		
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Albuminoid (Wanklyn).	Organic (Kjeldahl).	Total.	Filtrate.	Total	Permt.	Tempy.
Crude	77·2	67·6	38·4	9·6	6·4	0·03	0·37	0·87	11·44	0·81	6·0	5·1	0·9
Settled and filtered . . .	15·4	4·2	2·8	11·2	7·2	0·01	0·03	0·08	0·97	0·34	4·6	3·8	0·8
First washings	727·9	696·7	450·4	31·2	20·2	0·38	2·31	5·30	37·03	0·75	28·1	16·9	11·2
Mixed crude	219·1	197·2	125·8	21·9	14·8	0·21	0·79	2·25	15·15	0·56	16·0	10·2	5·8
Settled	20·5	3·1	2·7	17·4	10·8	0·08	0·01	0·03	0·45	0·32	11·0	7·4	3·6
Settled	11·3	1·3	1·3	10·0	5·0	...	...	...	0·24	...	6·0	4·2	1·8

public water supplies, the surface layer of sand becomes clogged with peaty matter, mud, or vegetable growths, and has to be removed from time to time and thoroughly washed in a stream of running water, or in a mechanical washer such as that of Greenway, in which the sand is propelled along a horizontal tube by means of a series of paddle blades and meets a current of water which washes it. This sand-washing water is much too impure to be discharged into a stream (see Table LXXIII.), but the impurities can easily be removed by effective settlement in tanks or ponds, followed where necessary by straining through sand filters.

Ore Washing.—As the ores of most of the metals such as lead, tin, and copper are much heavier than the rocks with which they are associated, the two can be separated, when crushed into a coarse powder, by the aid of water, in the same way as coal can be freed from shale and pyrites (see Chapter II.). The water coming from these washing operations is in all cases liable to carry with it large quantities of sand and mud washed out of the heavier ore and, mixed with this, more or less of the ore itself.

Most of these ores are fortunately insoluble in water, so that if the solid matters are deposited by settlement the resulting effluent can generally be discharged to the stream without producing any effect beyond a slight muddiness. In some cases the solids are so finely divided that they take a very long time to settle, and any settling tanks provided would therefore have to be of great size. In such cases, as has already been mentioned in dealing with coal-washing water, settlement can be greatly hastened by dissolving small amounts of lime in the water.

Refuse of this kind was very fully considered by the Rivers Pollution Commission, 1868, and is dealt with in their Fifth Report. They suggest (p. 49) that such refuse should be allowed to be discharged into a stream after having been subjected to perfect rest in subsidence ponds of sufficient size for a period of at least six hours, or, if not thus treated by subsidence, if it does not contain more than 3 parts per 100,000 of dry mineral matter. At the present day quiescent settlement is only rarely adopted, tanks being so constructed that the refuse runs continuously through them at such a low velocity as will not prevent the solid matters from settling.

China-clay Washing and Grading.—China clay, either from the clay pits in Cornwall or in potteries, is cleansed from sand and grit or graded by being carried by a current of water through a series of settling tanks or channels where the clay is deposited in different grades, according to the velocity of the current. It is difficult to settle the whole of the clay, and the effluent water is frequently very muddy, and requires treatment just as ore-washing waters do.

In a recent number of the *Journal of the Royal Society of Arts* (26th January 1912, p. 274), Professor Gee has described a simple form of centrifugal machine (Patent No. 16,188, 1911) for separating china clay from the water and at the same time grading it. The apparatus appears to be suitable for the separation of solids from liquids in many cases other than the one mentioned, and a description may therefore be useful. The apparatus

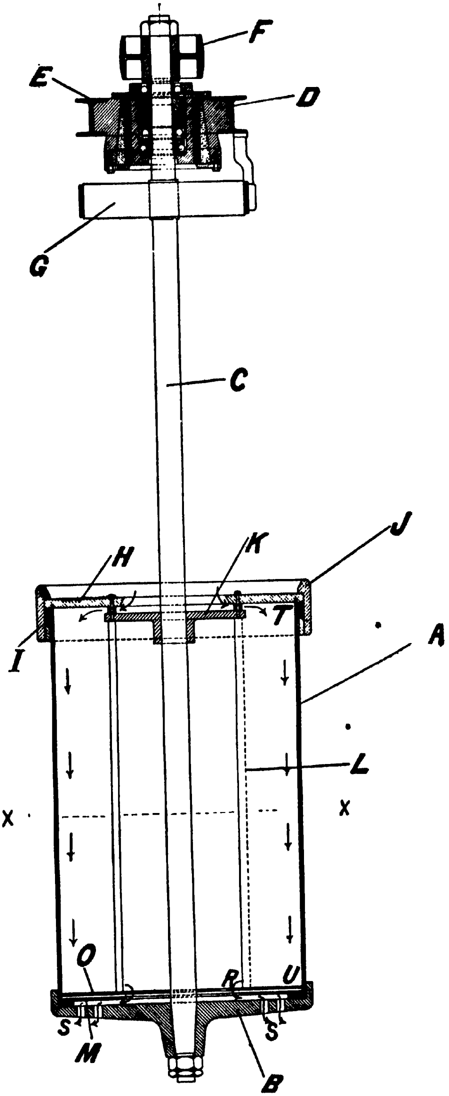

Fig. 38.—Gee's Centrifugal (Sectional Elevation).

is seen in sectional elevation in Fig. 38, and in cross section in Fig. 39. The drum A, fitted with a base B, is mounted on a shaft or spindle C, the whole being suspended from a ball-bearing of special design at D, supported between girders at E. Rotation is imparted by the pulley F, to which a hand-brake is fitted at G. The upper end of the drum is closed by a cap H, which makes a water-tight joint with the drum at I, when clamped by the locking-ring J. This forms a species of bayonet joint. The cap H has a hole in the middle, and is held central on the spindle by means of the casting K, which is a sliding fit on the spindle, and is connected with the cap by the upper ends of the six rods L. At the bottom of the drum at M is fitted a weir-plate or diaphragm. Depending from the cap into the drum is a kind of cage or "container," seen best in the section, consisting of six vertical square rods LL, to which are attached radial vanes or blades NN. These blades extend the whole length of the drum, being connected to the cap at the top end, and to a circular plate O at their lower end. The container slides easily in the drum, which it divides into six longitudinal compartments. Each compartment is provided with a curved plate P. It will be understood that the container is, in effect, a removable lining to the drum, on which the recovered solids are received, as shown in the horizontal section at Q. The operation of the machine is as follows :—

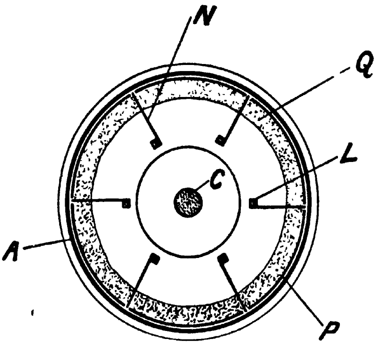

Fig. 39.—Gee's Centrifugal (Cross Section)

The requisite speed (usually between 100 and 200 feet per second peripheral velocity) being attained, the water, containing in suspension the solid matter to be separated and graded, is fed in a steady stream through the hole in the middle of the cap on to the casting K, which serves the purpose of a distributing plate. The centrifugal force generated by the rapid rotation causes the water to fly to the wall of the drum and distribute itself thereon, so that an inner wall of water is soon formed which, when a given thickness is attained, overflows, as indicated by the arrow at R, and passes out of the drum through the holes in the bottom, under the weir-plate M at S.

It will be understood that a slow, steady current of water is thus set up in the drum in the direction of the arrows, and in passing down the drum the solids in suspension are gradually deposited on the plates which line the drum. The coarse or heavy particles are very quickly separated, and these are found near the inlet at T. The finer particles are carried further along before they become separated, until the finest are deposited at U, near the outlet. Consequently the slab of recovered material ranges from the coarsest at one end to the finest at the other, with every possible degree of quality in between. The effluent water is said to be quite clear. When a sufficient charge of material has been recovered, the machine is stopped, the cap is unlocked, and the container drawn up by lifting gear until the bottom plate O is within a few inches of the top end of the drum. The curved plates can readily be removed, with the slabs of recovered material adhering to them; fresh plates are inserted, the container is lowered into the drum and locked, and the operation repeated. Four to five "journeys" per hour are made, and each operation in the usual-sized drum (3 feet diameter by 4½ feet long) recovers about a quarter of a ton of graded material.

Mineral-water Manufacture, Clay Mixing, Flint Grinding, File Scouring, and Cutlery Grinding.—The refuse from these trade processes all consists of mineral matters in suspension in water, much of the same nature as the discharges from stone sawing or ore washing, and it can readily be purified in the same manner.

Varnish and Paint Manufacture.—The polluting discharges from works employed in these trades are chiefly washing waters from swilling the floors and utensils, and the most polluting of these is the hot water which has been used with soda for cleansing the various receptacles for containing the finished products. This latter discharge is only small in amount, and can be purified by neutralising with acid and passing it through tanks with a series of scumboards for the retention of oily matters, followed by straining filters of fine material. The floor-swilling water can be passed directly on to the straining filters.

Beet-sugar Manufacture, Sugar Refining, and Starch Manufacture.—These trade processes are not of common occurrence in this country, and where they are met with, the refuse is almost always discharged into the sea or into tidal waters. The waste waters are highly polluting in character, containing large amounts of vegetable organic matters in solution and suspension. They lend themselves, therefore, to a final purification by biological methods, which can be greatly assisted by preliminary chemical precipitation and settlement of solids. The purification of this kind of refuse has received much more attention on the Continent than in this country, and it may suffice here to refer to the bibliography of the subject at the end of the chapter. It should perhaps be mentioned that the treatment of such refuse is not altogether without return, as the recovered solids can be dried and used as food for cattle.

Working of Salt Deposits.—In extracting potassium salts from deposits in Germany in the valleys of the Elbe and Weser, a mother liquor is left which has caused great trouble by being discharged into these rivers or their tributaries. This liquor contains large amounts of magnesium salts, and as the river waters are used for the domestic supply of various towns, the presence of these salts has been found very obnoxious. This kind of pollution, however, is not found in this country, and those who are interested may refer to the bibliography at the end of the chapter. Similar pollutions, but much less extensive, occur in the separation of common salt from brine in the county of Cheshire, and at a few places where Glauber's salts are prepared.

Conclusion.—There are many other trades, such as the making of confectionery and preserves, the manufacture of margarine, candle making, purification of rubber, and the distillation of wood, which give rise to polluting waste waters, but apparently nearly the whole of such trade premises are drained to sewers, and in any case where it may be necessary to purify the waste waters separately it should not be difficult, guided by the information given in these pages, to choose a satisfactory method. Although, indeed, methods of purification have been suggested as applicable to each of the trade waste waters described, the scheme best suited to any individual case can only be devised by bearing in mind the object of all these purification processes—the simplest effective method of removing objectionable matters.

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CHAPTER XI.

PUMPS, SCREENS, TANKS, FILTERS, AND OTHER APPARATUS.

Pumps—Screens—Simple forms—Longwood Engineering Co.'s screen—Kent's screen—Chambers and Hammond's screen—Other forms—Meters—Settling tanks—Principles of construction—Septic tanks—Chemical precipitation Sludge treatment—Burying in trenches—Sludge-drying filters—Sludge pressing—Straining filters—Biological filtration—Percolating filters—Distribution of liquid on filter—Slate beds and contact beds—Land treatment—Evaporators and incinerators—Porion evaporator—Scott's multiple-effect evaporator—Yaryan evaporator—Kestner boiler and evaporator—Scott's revolving incinerator—Conclusion—Bibliography.

In dealing with the purification of refuse from individual trades and in explaining the methods adopted in particular cases, descriptions have already been given of many kinds of apparatus used, but it may perhaps be useful, and will serve to show that there is in every case a choice of methods, if the various operations and the forms of apparatus suitable at each stage of the purification process are discussed in detail.

Pumps.—It is impossible within reasonable limits to describe the various forms of apparatus used for raising waste waters and sludge. These may be found described in detail in text-books on mechanical engineering. It may suffice here to point out that many waste waters act injuriously upon the metal of which pumps are ordinarily constructed. In many cases, therefore, it is necessary to see that pumps are made of gun metal or other acid-resisting material. For lifting sludge, steam injectors, such as are made by Messrs Mather and Platt, Ltd., Salford, have been found useful. They are not to be recommended for continuous work, such as, for instance, the pumping of the entire volume of trade waste water, inasmuch as their steam consumption is comparatively great; but this objection does not apply to their use for lifting sludge, as that is only done at considerable intervals and for short periods. For short lifts diaphragm pumps are found very useful for sludge, and where the sludge contains fibre or other obstructive solid matter chain pumps can be employed. Or, the plan in use at many sewage works can be adopted, where sludge is run into an air-tight receiver and blown out by compressed air. These few instances may serve to show that it is always necessary in choosing a pump to consider carefully the nature of the liquid to be dealt with.

Screens.—Many kinds of trade refuse contain quantities of fibrous matter and coarse solids, and these it is better to remove as a preliminary step in purification, as otherwise they may interfere with the proper working of pumps, greatly increase the volume of sludge produced by the after treatment, or choke up any filters which may be used.

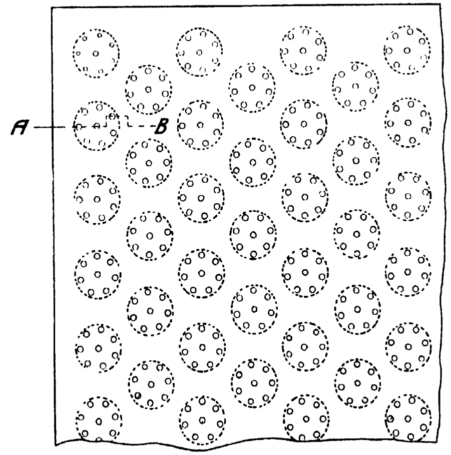
Where the object of screening is simply to prevent the passage of materials which would interfere with pumping, it is generally sufficient to partition off the corner of the pump well in which the suction pipe is placed by means of a vertical or sloping screen of parallel iron bars, some $\frac{1}{2}$ inch in diameter and $\frac{1}{2}$ inch apart, and this can be easily cleaned by means of a rake.

The fibrous matter, if recovered by itself, has frequently a substantial value, as, for instance, that which accompanies the refuse from piece-scouring and waste-cotton bleaching (see pp. 179 and 105); while amongst the coarse solids, which it is better to remove by screening than to permit to pass on into settling tanks, are, for instance, the light and defective grains in grain-washing waters and the spent woods in dyewaters (see pp. 56 and 130). For the removal of these fibres and other solids several kinds of screening apparatus are available.

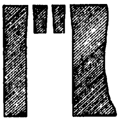
One of the simplest arrangements consists of a box, the bottom of which is formed of perforated copper. Into this the trade refuse is discharged, when the fibrous or other solid matters are retained and can be brushed off, the liquid escaping through the perforations. This kind of screen is frequently adopted in mills in the wool trade, one being placed at the outlet from each washing machine. It is found, however, that a great deal of fibrous matter escapes arrest; in one case as much as 25 per cent. of the fibrous matter recoverable was found to have escaped through such a sieve box.

A better arrangement is to form the bottom of the sieve box of maltkiln tiles (see Fig. 40), such as are used for the floor of every maltkiln. These tiles are usually 12 inches square and 2 inches thick, and are made of glazed earthenware with numerous perforations arranged in a particular manner. On looking at the under surface of the tile a series of holes is seen, about $\frac{7}{8}$ inch in diameter and $\frac{3}{16}$ inch apart, and not penetrating through the tile, but leaving a shell on the upper surface about $\frac{3}{4}$ inch thick, through which small conical perforations are made about $\frac{1}{12}$ inch in diameter at the top, and about $\frac{3}{16}$ inch at the bottom. On looking at the upper surface of the tile these small perforations are seen in circular groups. When these tiles are used in the sieve box of a piece-scouring machine it is found that the liquid part of the scouring refuse escapes more freely than through a copper sieve, leaving the fibres on the tile, and that these fibres are easily brushed off from the glazed surface. The cost of this form of screening apparatus is insignificant, as the price of the tiles is only about a shilling each, and any joiner can readily put together the box to contain them.

When a screen is provided on the general outlet drain from a mill it may take one of the above forms, but more commonly is on a different plan. If the drain is a wooden trough a series of iron spikes is often arranged projecting upwards into the liquid from the bottom of the trough, and on these the waste fibres become entangled, to be removed from time to time by means of a rake. Obviously this form of screen can only be used for the recovery of fibres of some length, such, for instance, as those escaping from wool washing.



PLAN.



SECTION AT A-B.

FIG. 40.—Maltkiln Tile.

All the above forms of screening apparatus are gradually being displaced by automatic and much more effective machines, one kind of which has been in use in a simple form for many years at various mills, but has been patented in an improved form by the Longwood Engineering Co., Ltd., Longwood, near Huddersfield.

Fig. 41 shows this machine. The liquid to be screened is passed through a half cylinder of perforated copper, 144 perforations to the square inch, and each perforation $\frac{1}{24}$ inch in diameter. On this screen the fibres in the refuse are entangled, and before they have time to pass through the perforations they are caught up by a revolving brush and deposited in a box. The fibres are thus well washed in the rush of water, and, to a considerable extent, dried by the brushes pressing them against the copper sieve, and means are provided for adjusting the brushes from time to time as they are worn down. The apparatus is, therefore, almost automatic, the only attention required being the removal of the collected fibre. The revolving brush in the figure is shown to be driven from the shafting of the mill, but in cases where there is a sufficient fall on the mill drain the flow of the refuse may be made to drive a small water-wheel, from which sufficient power can be obtained to drive the brushes. This apparatus is extremely effective, and in an ordinary woollen mill may

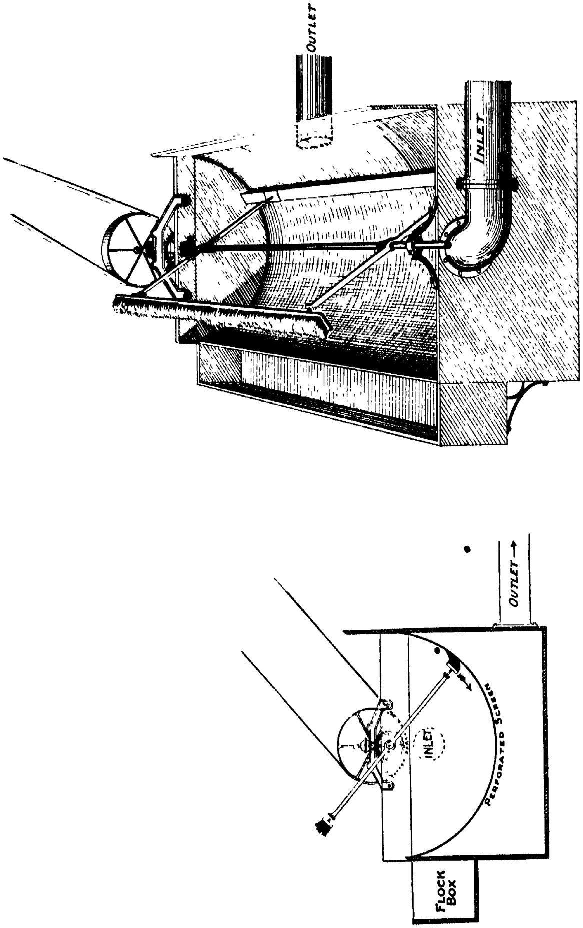


FIG. 41.—Patent Screen. (The Longwood Engineering Co., Ltd.)

often be counted upon to recover in a year sufficient fibre from the refuse waters to pay for its installation. The cost of an apparatus of this kind to deal with a flow of 1000 gallons an hour would be about £20. For a larger flow, say 14,000 gallons an hour of piece-scouring refuse, or double that volume of dyewater, the cost would be about £35.

Another somewhat similar screen, made by G. Kent, Ltd., High Holborn, London, large enough for a flow of 10,000 gallons per hour, is shown in Fig. 42, and costs about £15.

Messrs Chambers & Hammond, Chemical Engineers, Huddersfield, have recently brought into use a patent screen (No. 7090, 1912) in quite another form, as shown in Fig. 43. They propose that it should be used in the form shown for dealing with wool-washing suds. Two circular vertical screens revolving on the same shaft are placed in the course of the mill drain, with a catchpit between them to retain sand and other heavy impurities. The screens are formed of perforated copper, the perforations in the first being much larger than those in the second, and the copper is stretched upon a vertical iron wheel which revolves in a chase in the drain and up against a back plate, which prevents the escape of the liquid except through the screen. The fibrous matter is automatically removed from the screen by means of what may be termed a "rubbing plate," or board fixed vertically against one quadrant of the rotating screen at a distance of ¾ inch from its face. The fibre screened out of the effluent is entrapped between the screen and the rubbing plate, and, when sufficient has accumulated, is compressed into rolls which are

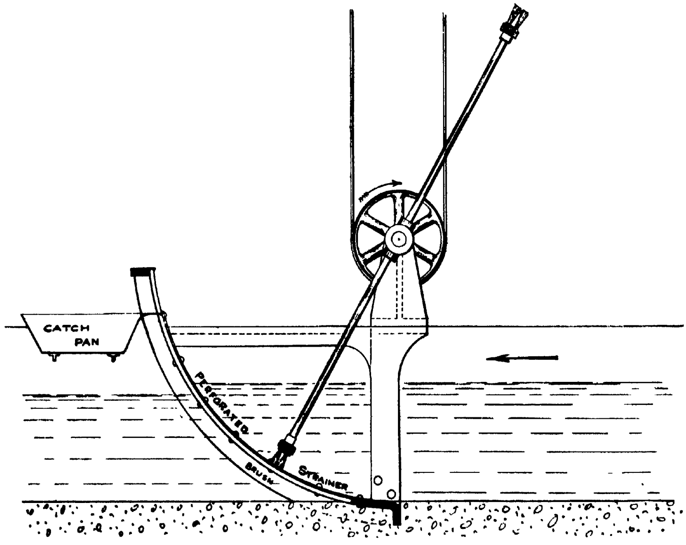


FIG. 42.—Kent's Screen.

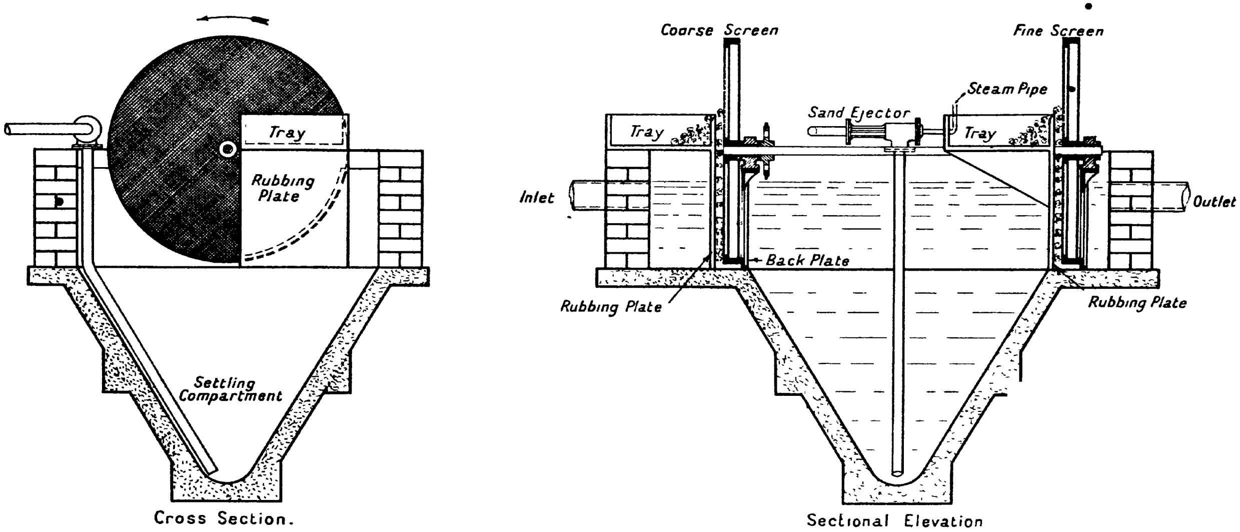


FIG. 43.—Automatic Flock Screen. (Patented by Chambers & Hammond, Huddersfield.)

finally discharged over the top of the rubbing plate into a tray placed for its reception. The power required to work a 6-foot screen, which is sufficient to deal with a flow of 15,000 gallons per hour, is said not to exceed ¼ H.P., and in one such case the amount of wool recovered is said to be 100 lbs. daily. The cost of the apparatus shown in the figure, including the settling tank, and large enough to deal with 1000 gallons an hour, would be approximately £32, and for a flow of 10,000 gallons per hour £72. A single screen to deal with 10,000 gallons per hour would cost about £40.

Yet another form of automatic screen which has been used for screening dyewaters is that patented by Mr Pearson and used for many years at one of the branches of the Bradford Dyers' Association. A very similar screen is described and illustrated in the *Mitteilungen aus der Königlichen Prüfungsanstalt*, Berlin, 1908, vol. 10, p. 104, as in use at a woollen mill near Berlin, and it has been introduced into this country by the Chadwick Machine Co., Ltd., Textile Engineers, Cleckheaton. These two screens are in the form of a revolving cylinder covered with perforated copper or wire gauze. The refuse is discharged into the interior of the cylinder, when the water escapes through the perforations, and the fibre, caught on the inner surface of the perforated lining, is carried by the revolution of the cylinder to a point where in one case it is removed by a "doctor" or scraper, and in the other case is blown by compressed air or steam on to a conveyor or travelling band which deposits it in a receptacle provided for the purpose.

Two other forms of screen have been described in connection with the treatment of grain-washing refuse.

Meters.—In all cases it is advisable, and in some cases, as, for instance, when trade refuse is received into a sewer on terms of payment, it may be necessary to use a meter to record the flow. Such a meter should always be placed so as to measure the flow of the refuse after the fibre and gross solids have been removed by screening, as these would otherwise interfere with the working of the meter. In some cases it may be found convenient, and it would certainly always give more reliable results, to measure the effluent after purification.

There are many forms of meter on the market. One of the simplest is in the form of a single or double tipper (see p. 272), which passes on a definite volume each time it discharges. To the axle of the tipper a ratchet arrangement is fixed, by means of which the number of discharges is recorded, so that it gives a very reliable measurement of the total volume passing during any given period. This arrangement is not suited to the measurement of large volumes, as the wear and tear on a large instrument is very great.

In the water softener of Lassen and Hjort the contrivance adopted for the measurement of chemical precipitants (see p. 260) is actuated by such a tipper, and can readily be made to record the flow of water passing through it, as well as to regulate the quantity of precipitant.

Another form of meter, more suitable for the measurement of larger volumes, is the Lea recorder, made by the Lea Recorder Co., Manchester. This is in the form of a tank with a V-shaped notch outlet, provided with a float and clockwork recorder which gives the rate and amount of flow in a diagrammatic form. The accuracy of this instrument depends upon the true setting of a curve upon a metal cylinder, and in all cases it is necessary to check this by some other means of measurement, as, for instance, the filling of a tank, but when such a check has once been carried out the results are very reliable. The cost of an instrument of this kind to measure a flow approximating 1000 gallons an hour is about £30, and for a flow of 10,000 gallons an hour £40.

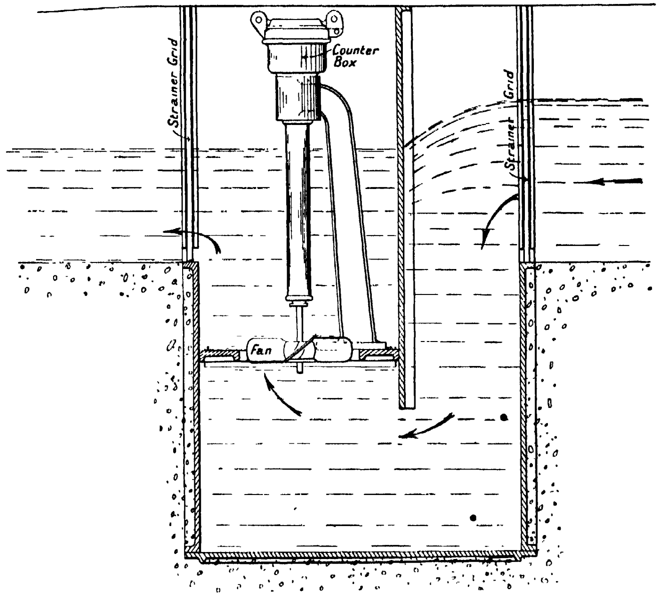


FIG. 44.—Kent's Meter for Trade Refuse.

Another form of meter which has been found useful, for example at Huddersfield, for recording the flow of trade refuse discharged into the sewers, is made by G. Kent, Ltd., and shown in Fig. 44. The refuse is made to rise through an orifice in which a small turbine or fan is placed, and by means of the revolutions imparted to the fan the quantity of liquid passed is shown upon a counter. The price of a meter of this kind to deal with a flow of 10,000 gallons per hour would be about £10, but if a mechanical strainer is added, and this is usually necessary, the total price would be £25.

Messrs Kent also make a V-notch discharge recorder ("Irrigation" meter), shown in Fig. 44A, which has been successfully used for measuring the flow of trade refuse.

Kent's Venturi meter, well known in connection with measuring water supplies, can also be used for measuring waste waters, and as the firm have recently patented a method of measuring chemical precipitants according to the flow, by means of a Venturi tube, a combination of the two inventions may be found extremely useful (see p. 262). A 2-inch recording Venturi meter for a flow of 1000 gallons per hour costs £90, while a 6-inch meter for a flow of 10,000 gallons per hour costs £135.

Other water meters, for example the Helix and the Bee meters, made by the Leeds Meter Co., Ltd., for smaller flows, and Glenfield and Kennedy's meter for larger, are also suitable for the measurement of refuse waters.

Settling Tanks.—In preceding chapters descriptions and illustrations have been given of several forms of settling tank. The most primitive form is that of a square or oblong tank, into which the liquids are received and allowed to undergo quiescent settlement. This form is still generally used in seak tanks for the recovery of grease from soapy liquids (see p. 112). In the Archbutt-Deeley process of Messrs Mather and Platt, Salford, such tanks are also used both for water softening and for the purification of trade refuse, but the deposition of the solids is assisted by a patent device. Some of the sludge is always retained in the tank, and after the tank has been filled with the liquid to be treated, and after the addition of the precipitant, this old sludge is blown up by a current of air so as to mingle thoroughly with the rest of the tank contents. By this means all the finer suspended matters are agglomerated into particles of larger size, which readily settle when the agitation of the tank contents ceases. The results of this method as applied to the refuse from a woollen mill are given on p. 158.

The adoption of this quiescent form of settlement entails considerable attention, inasmuch as someone must be present to close the inlet of the tank when it is filled and to let off the liquid contents and the sludge at proper times.

Quiescent settlement is not, however, necessary, for it has been found that even when the liquid is passing continuously through a tank of sufficient capacity the lessened velocity causes almost complete settlement of the suspended solids. When the liquid enters by a pipe inlet and escapes by a similar outlet the solids chiefly settle in that part of the tank which lies directly between the inlet and the outlet, and the settlement is very incomplete unless the capacity of the tank is very large in comparison to the flow of liquid. The effectiveness of such a tank is enormously increased by causing the liquid to enter over a sill which extends the whole width of the tank, and to escape over a similar sill, and this can easily be attained by interposing a wooden trough at the inlet and again at the outlet (see Fig. 32). This arrangement, as stated on p. 184, equalises the velocity of the current over the whole width of the tank and reduces it to a minimum. In such a tank the movement of the liquid is for the most part confined to the superficial layer, especially if the liquid is warm as it enters.

As has been frequently mentioned, the waste waters coming from a mill vary greatly in character at short intervals, and better results are obtained if the various liquids are mixed as thoroughly as possible. This is best attained by the provision of a preliminary mixing tank (see p. 140), in which some form of stirring apparatus may be provided (see p. 175), or, where the liquids have to be pumped, by making the pump well of sufficient size; but the same advantage may be to some extent gained by placing a baffling wall or wooden partition across the whole width of the settling tank, by means of which the incoming liquid is directed downwards and made to mingle with the body of liquid already in the tank (see pp. 184 and 196). As suggested on p. 197, such a baffle wall should not reach down too near to the bottom of the tank, or the incoming liquid will stir up and carry along with it some of the solids already deposited.

The tendency for the movement in a liquid passing through a tank to affect mostly the superficial layer has much to do with the settlement of suspended solids; these, as they are carried down by gravity out of the more rapidly moving liquid, fall into comparatively quiescent layers, where they have increased opportunity of settling to the bottom of the tank. This fact is often taken advantage of in tanks of considerable length by interposing a submerged wall across the middle. Such a wall reaches from the floor to the same level as that of the inlet and outlet sills, so that the liquid passes over it in a thin stream, and behind it there is formed a comparatively quiescent pool in which the solids can more readily settle.

In nearly all cases it is necessary to provide scumboards for the purpose of preventing floating solids from escaping in the tank effluent. The simplest form of scumboard consists of an 11-inch plank placed so as to float edgewise across the whole width of the tank; when floating freely between guides such a plank will always stand about 2 inches out of the water. It should be placed within a foot of the outlet sill, when the effluent will escape from underneath it and leave the floating solids behind (see Fig. 37).

In a settling tank such as the above the floor should be formed in such a way as to facilitate the settlement of the solids and the removal of the resulting sludge. The bulk of the solids, especially the heavier portion, settles near the inlet end, and the tank should therefore be deepest at this end and should have the sludge outlet here. The floor should have a considerable slope towards this end, say 1 in 40, so that the sludge, if very liquid, will flow to the outlet, or can easily be pushed down by means of a broom or squeegee.

When a tank is being cleaned it is never satisfactory to deal with the liquid contents along with the deposited sludge, and an elbow-jointed pipe or floating arm (see Fig. 45) should always be provided in order to decant the top water before discharging the sludge. Another contrivance of this kind is shown in Fig. 46; the decanting valve consists of a cast-iron standard in water-tight sections set within a tank, and each section can be raised in turn by means of a screw, so that the tank contents can be drawn off in layers.

Perhaps the best arrangement of settling tanks such as the above is that shown in Fig. 37. The method of use and its advantages are set out on p. 196. Tanks arranged thus have been introduced at the sewage works of the Bradford Corporation, and it may be noted that whereas with an older form of settling tank the sludge produced was always very liquid, containing over 95 per cent. of moisture, it is now easy to obtain a sludge with less than 85 per cent.

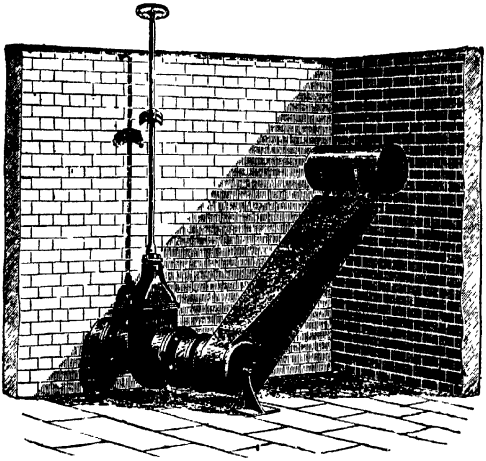


FIG. 45.—Floating Arm. (From Dunbar's *Sewage Treatment.*)

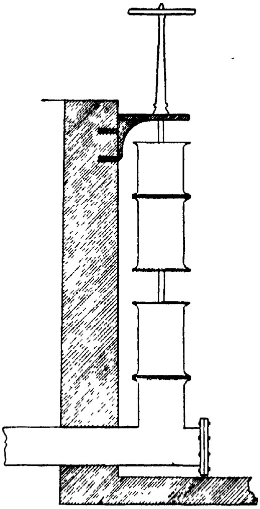


FIG. 46.—Decanting Valve.

The value of this reduction of moisture can be appreciated from the curve shown in Fig. 47. The ordinates of the curve, using the upper row of figures, represent the tons of sludge, containing one ton of dry solid matter, when the moisture present is varied from 0 to 90 per cent., these percentages being indicated by the abscissæ. By using the lower row of figures the same curve shows the rapid increase in the weight of sludge, containing a constant amount of dry solid matter, as the percentage of moisture is increased from 90 to 99. Thus in the former case, if no moisture is present there is a ton of dry solid matter; if there is 50 per cent. of moisture, 2 tons of sludge contain 1 ton of dry solid matter; whereas if 90 per cent. of moisture is present, there will be 10 tons of sludge although the dry solid matter is not increased. In the latter case a ton of sludge containing 90 per cent. of moisture will be increased to 5 tons if 98 per cent. of moisture is present, although it contains the same amount of dry solid matter.

A new form of settling tank (see Fig. 48) has recently been brought into use by L'Épuration, Société anonyme, 59 Rue de Namur, Brussels, in their Vial system of sewage purification and water softening. Tanks of this kind have been constructed at Ostend Sewage Works. Each tank there is 147 feet long, 16½ feet wide, and has a capacity of 275,000 gallons, equal to the daily quantity of sewage passing through it.

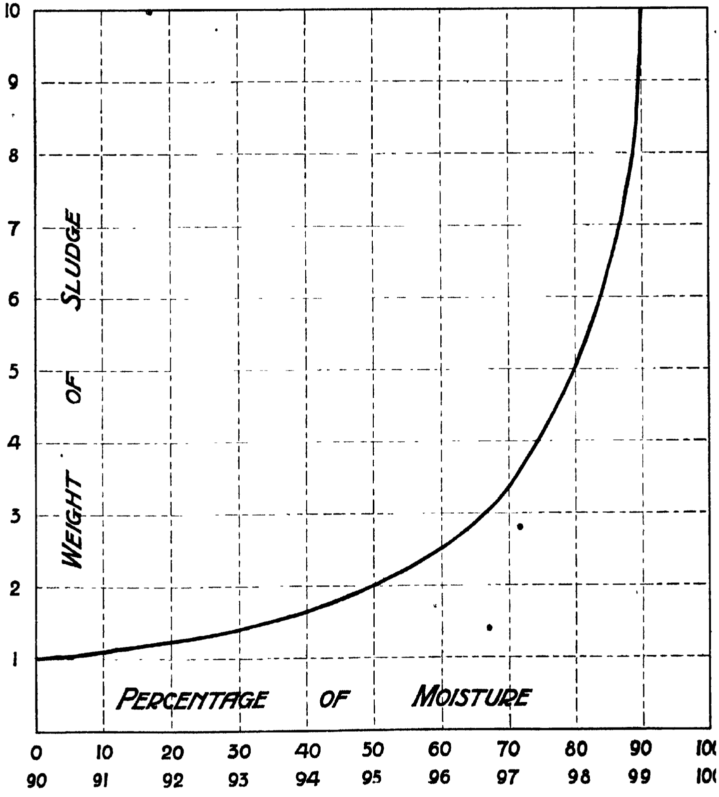


FIG. 47.—Relation of Weight to Moisture in Sludge.

The sewage passes into each over a sill extending over the whole breadth of the tank, first into a wedge-shaped compartment 15 feet deep, where the grosser solids settle, and then over a submerged wall into a larger compartment, the bottom of which is of the same depth at the inlet

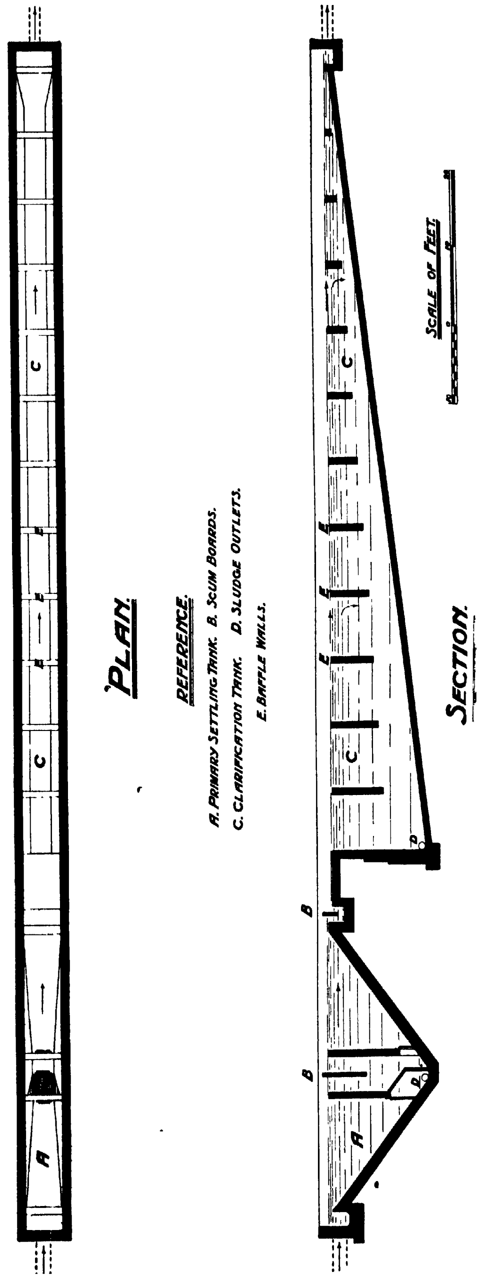

PLAN.
REFERENCE.
A. PRIMARY SETTLING TANK. B. SCUM BOARDS.
C. CLARIFICATION TANK. D. SLUDGE OUTLETS.
E. BAFFLE WALLS.
SECTION.
SCALE OF FEET.
A
B
B
C
C
D
D
E
E
E
E

FIG. 48.—Settling Tank (Vial System). (Société anonyme, L'Épuration Brussels.)

end, but slopes upwards to an outlet sill at the further end. In this second compartment eleven submerged walls are provided, each extending across the whole width of the tank and to some depth in the liquid, but not to the bottom of the tank, and over each of these the sewage flows in a shallow stream about half an inch in depth. Scumboards are also provided to keep back floating matters. The object of this arrangement is to make the sewage flow from one end of the tank to the other in as slow and as superficial a current as possible, while the main body of the liquid in the tank is kept nearly quiescent, so as to allow of the settlement of the suspended solids immediately they fall out of the current, the submerged walls serving the purpose of checking the current underneath the surface and directing downwards the particles of suspended matter. The sewage is said to take about fifteen minutes to pass through the tank.

The sludge is discharged from the tanks by bottom valves under pressure of the head of water, three times a day from the first or wedge-shaped compartment and continuously in small amount from the second compartment. It is therefore necessarily very liquid in character, containing about 95 per cent. of water.

In the tanks already described the main flow of the liquid is in a horizontal direction, but it is found that in a settling tank in which the liquid is made to flow in an upward direction the suspended solids carried in it are more readily deposited or left behind by the current, when that is sufficiently slow. The deposition of the suspended matter with such an upward flow is probably in great part assisted by the entanglement of the finer particles, which are being carried upward in the current of liquid, by the grosser particles as these fall to the bottom of the tank. Perhaps the earliest form of upward-flow settling tank is that known as the "Dortmund," which was adopted for the settlement of the Dortmund sewage about 1886. Many variations of this tank have been introduced, and one of the best known is that used at the Birmingham Sewage Works for the separation of the humus or fine suspended matter from the effluents of the percolating filters, and this, by the kindness of Mr J. D. Watson, is shown in Fig. 49. This tank has a pyramidal bottom and is square in the upper portion, the liquid entering by a pipe which dips down into the middle of the tank, with a velocity at entry of 1 to 2 feet per second. As it emerges from the pipe it spreads out laterally and rises in the lower portion at a gradually decreasing velocity, until it reaches the upper portion, through which it rises at a rate of some 7 feet per hour. This check in velocity allows particles in suspension to fall to the bottom of the tank, and, in falling, to entangle and agglomerate other particles. The sludge thus collected is forced into the sludge pipe by the pressure of the overlying water on opening a valve, and the sludge pipe is arranged vertically so that any obstruction can be pushed out by a rod. The settled liquid escapes over a series of wide weirs on the wall of the tank, so that the velocity of exit is checked.

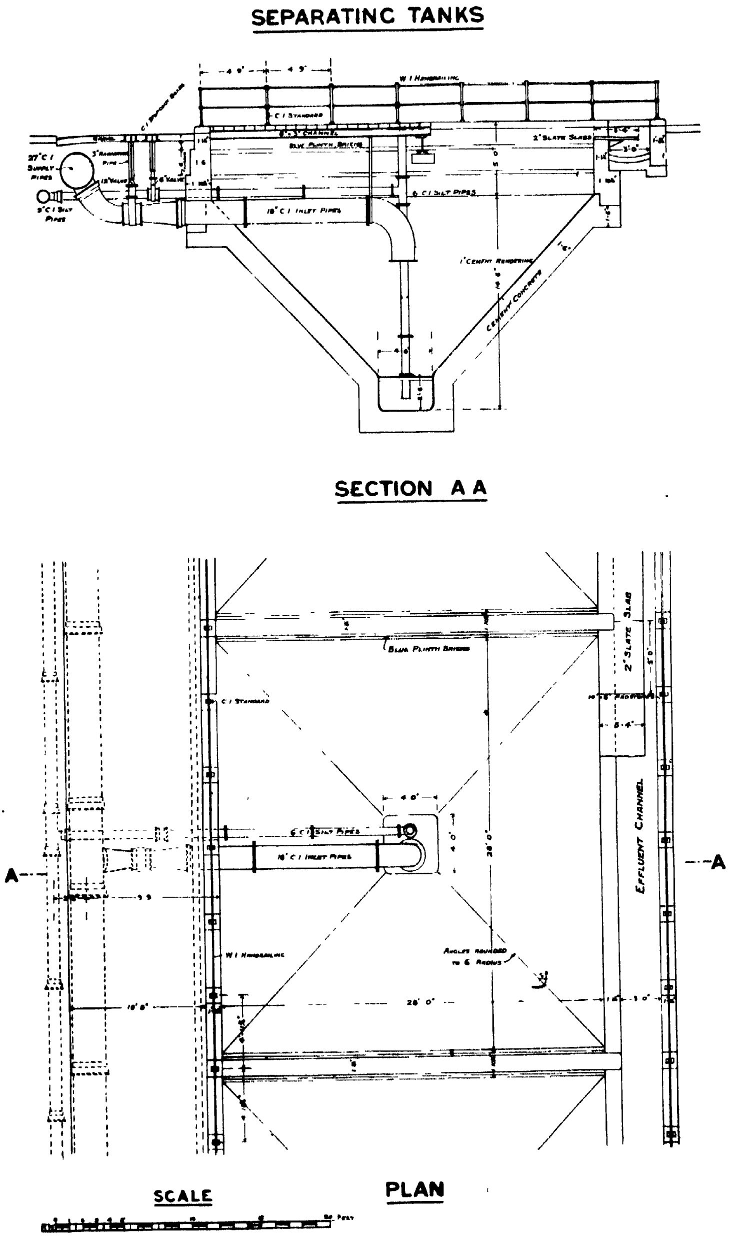


Fig. 49.—Birmingham Silt Tanks.

Another tank of similar form, shown in Fig. 50, has recently been sanctioned by the Local Government Board at Batley Sewage Works. This tank is provided with movable scrapers, worked from a central spindle, for detaching any sludge which may adhere to the sloping tank wall. Evidently better results could be obtained from this tank if the inlet pipe were prolonged downwards and the outlet were in the form of a weir or trough. These alterations have in fact recently been made with good results, and similar tanks, in which these improvements have been adopted, are shown in Fig. 29.

In another form of tank both the upward flow of liquid and the provision of a submerged wall have been adopted, as shown in Fig. 51. Tanks of this kind have been constructed at several of the sewage works of the Rotherham Rural District Council, and when made of a capacity equal to the average daily flow of sewage passing through them, have been found exceedingly effective in removing the solids from a precipitated sewage.

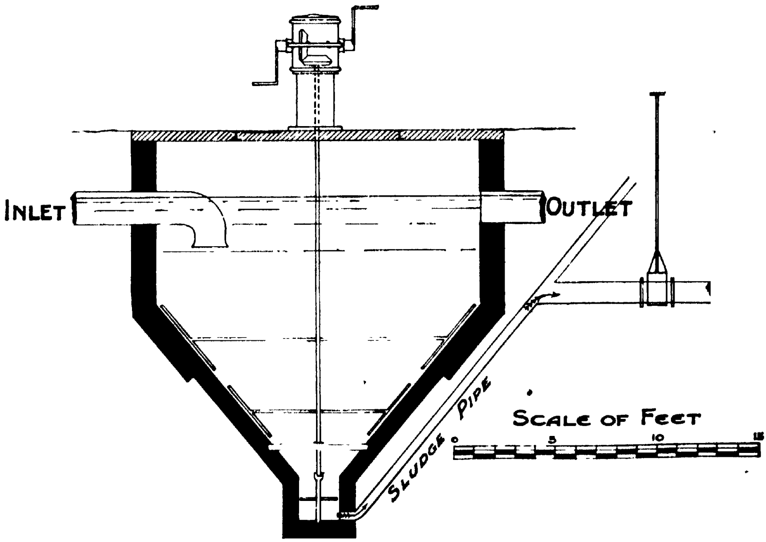


FIG. 50—Conical Settling Tank.

In Waite's apparatus, shown in Fig. 20, the principle of upward flow is adopted, and the advantage of reducing the velocity (see p. 133) is gained by dividing the liquid passing through the first tower between the two final towers.

In Mackey's apparatus (Fig. 22), although the principle of upward flow is adopted, an object altogether different is aimed at; the liquid is passed into the tank at its lowest point, where the sludge naturally collects, so that the incoming liquid must pass upwards through layers of

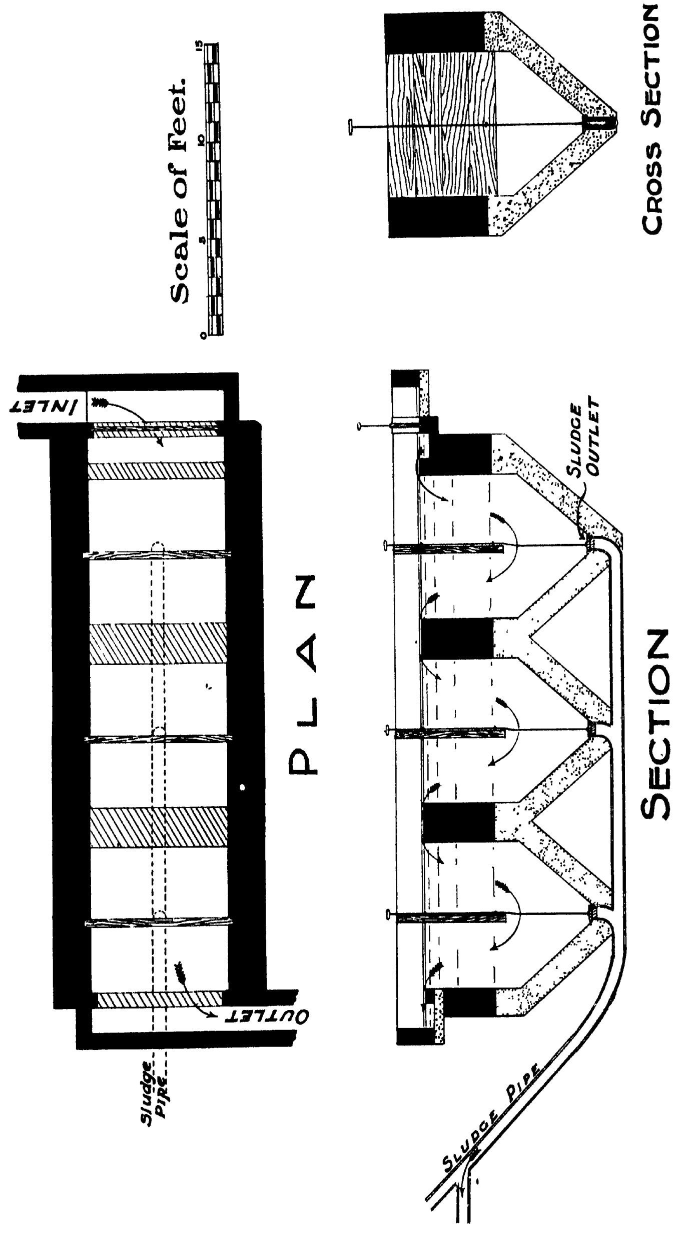


Fig. 51.—Settling Tanks with upward flow and submerged wall.

sludge previously deposited, and these entangle the suspended matters carried in the liquid, agglomerating the finer particles and converting them into coarser solids, in which form they settle more readily. This carries out continuously the principle which is carried out intermittently in the Archbutt-Deeley process (p. 156).

An ingenious form of tower for the settlement of suspended matters, which avoids the necessity for pumping, is that of the Gesellschaft für Wasserversorgung und Abwasserbeseitigung, Berlin (see Fig. 52), supplied in this country by the Septic Tank Co., Ltd., Westminster. In this apparatus, the inlet pipe, the sludge pipe, and the outlet pipe are all made to dip into small wells kept charged with liquid, that which receives the outlet pipe being at a somewhat lower level than that into which the inlet pipe dips. This difference in level is necessary to produce the syphonic action upon which the working of the apparatus is based. A fourth pipe has its origin in a funnel at the top of the vessel and serves for the escape of grease and other floating matters.

In commencing to use the apparatus the valves at the foot of the inlet, outlet, and sludge pipes are closed, while that on the grease pipe is opened, water is turned on from the water main, and the vessel is filled until the water overflows through the grease pipe. The valve on this latter is now shut, and those on the inlet, outlet, and sludge pipes are opened, when the syphonic action begins, and any water entering the small well at the inlet side is sucked into the vessel, rises to the top, and escapes by slits in the horizontal arms of the outlet pipe. Sludge settles to the bottom and escapes by the sludge pipe. Where the liquids dealt with contain greasy matters, these rise to the top and can be let off from time to time by closing the inlet, outlet, and sludge pipes, and turning on the water from the main. If at any time the syphonic action is stopped by the accumulation of air or gas at the top of the vessel, the air can be discharged by opening the valve on the grease pipe, closing all the other outlets, and at the same time turning on the water from the main just as when the apparatus is started.

All these tanks in which the principle of upward flow is adopted have a great advantage in that their shape permits of their being emptied of sludge by means of the head of water they contain, and while they are still in use. With this in view, care is taken to construct the tanks with a more or less conical bottom, into which the sludge falls as into a funnel. When a valve on this funnel is opened, any desired amount of sludge is forced out by the weight of superincumbent water. Sludge thus obtained is, however, very liquid, containing usually over 95 per cent. of water, but the method has the advantage that the sludge need not be drawn off at the level of the bottom of the tank (see Figs. 49 to 51), and thus little of the available fall is lost, and sludge filters can be placed at a higher level, an advantage which is often of considerable importance. It is found in practice that a head of 4 feet of water is sufficient to express the sludge.

The capacity of settling tanks required for the treatment of any waste waters is naturally dependent upon the volume to be treated, and upon the character and amount of the suspended matters present, and is also dependent on the form of tank chosen. In dealing with a liquid such as coal-washing refuse, where the specific gravity of the suspended solids is

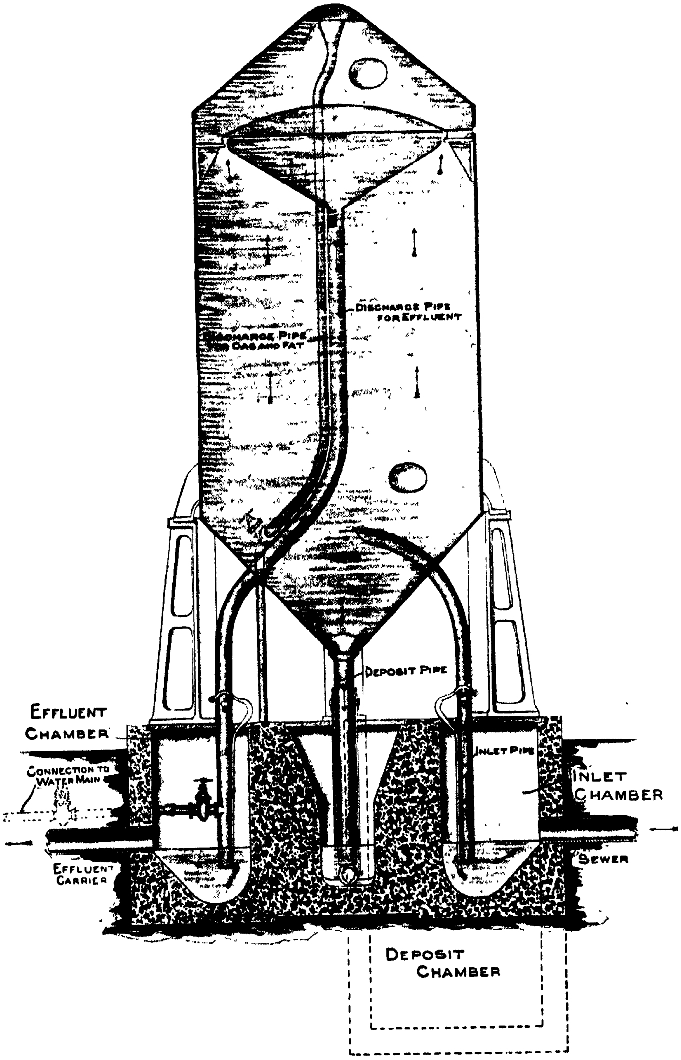


Fig. 52.—Patent Cylindrical Tank. (The Septic Tank Co., Ltd.)

high compared to that of water, so that they readily settle, ordinary tanks of a total capacity of half a day's flow are sufficient to allow of perfect settlement, but the deposited solids are so large in amount that they take up a good deal of the available tank capacity, and extra tanks are therefore necessary. For liquids such as soapy waters or dyewaters, containing suspended matter of low specific gravity, the rate of settlement is much slower, and tanks of larger capacity are requisite. For such liquids, ordinary settling tanks should be large enough to hold two days' flow. Where upward flow tanks, such as those of Waite and Mackey, and the Dortmund tank, are used, equally good results may be obtained with half this tank capacity. It must be borne in mind, however, that with tanks of the ordinary form it is always necessary to have one or more in reserve to be used while others are being cleaned out, so that, as has been pointed out (p. 196), it is of advantage in such a case to have them subdivided into a number of units, so that when one is being cleaned only a small proportion of the tank room is out of use. In choosing a particular form of tank regard must be paid chiefly to the available site and also to the necessity or advantage of pumping the refuse.

In devising a scheme which includes settling tanks of the ordinary form the labour of dealing with the sludge must always be kept in view, and if possible the tanks must be constructed so that the sludge will flow from them by gravitation. Should the natural fall of the ground be unfavourable, this can be accomplished by providing a sump, into which the sludge will flow, and from which it can be removed by pumping.

Septic Tanks.—In describing the methods adopted by various quoted authorities for dealing with liquids containing considerable amounts of organic matter, mention has frequently been made of treatment by septic tanks. These have no special form, except that they have to be arranged with an inlet and outlet both dipping underneath the surface of the liquid in the tank, and full descriptions will be found in all text-books on sewage disposal. The name given to them refers to the method of treatment adopted, in which the liquid is retained in the tank until putrefaction has so far advanced that the solid matters in suspension become partially broken down. When this method of treatment was first introduced it was hoped by the inventor that this breaking down of the solids would proceed so far that all organic matters would be brought into solution or gasified, and that the sludge difficulty would disappear; but this hope has not been realised, and the reduction of sludge is in no case very complete. Septic tank treatment of liquids containing organic matter can never by itself suffice to produce effective purification, and the opinion is now generally held that it does not serve to bring them into the best condition for subsequent biological treatment, as they are almost wholly robbed of dissolved oxygen and contain sulphuretted hydrogen. Septic tank treatment is seldom to be recommended for trade waste waters, and if it is adopted the deposited sludge alone should be allowed to become septic, while the clarified liquid is passed on for further treatment in a comparatively fresh state. This is the object aimed at in the Hydrolytic Tank of Dr Travis (see *The Surveyor*, 1908, vol. 33, p. 673), and the Emscher Tank of Dr Imhoff (see *The Surveyor*, 1909, vol. 35, p. 625).

Chemical Precipitation.—Chemical precipitants may be regarded as acting in two distinct ways upon the liquid treated. Some combine with dissolved matters to form or to liberate insoluble solids; others are used to produce voluminous precipitates which entangle fine particles suspended in the liquid, and greatly hasten their rate of settlement. For instance, lime is often used to precipitate a soapy liquid by the formation of a heavy lime soap, and acid is used to set free the insoluble fatty acids from a greasy liquid such as wool-washing refuse; while, on the other hand, lime with sulphate of alumina or with ferrous sulphate produces a voluminous hydrate which entangles fine suspended particles and forms a lake with colouring matter.

The choice of a proper precipitant and the amount to be used depend upon the nature of the liquid to be treated, and should always be decided from the result of laboratory experiments. Instances of the use of the commoner precipitants, lime, sulphuric acid, alumino-ferric or sulphate of alumina, and ferrous and ferric salts, have been given in describing the treatment of different kinds of refuse. It is obvious that if too great a quantity of any of these is used some will escape in the treated effluent, and may be harmful to discharge into a stream, but it is generally easy to guard against this. It is often, for instance, raised as an objection to the use of lime as a precipitant, that an effluent containing lime may be very harmful to users of the water lower down the stream into which it may be discharged, but if any lime escapes in the effluent it must be considered as needlessly wasted. The lime should be used as carefully as it is in softening a calcareous water, where it actually reduces the amount of the lime salts originally present in the water.

The methods adopted for adding precipitants are often extremely crude and wasteful. When lime is used it is too often thrown into the liquid in the solid unslaked form, when much of it falls to the bottom of the settling tanks and remains unutilised, or in some cases so much is added that the liquid is either rendered very hard, or the excess acts as a solvent of previously deposited sludge. When alumino-ferric is the precipitant, a slab of it is generally placed in the mill drain, where it dissolves away in quantities which are often either too small for effective precipitation, or so large that there is a needless waste. Where acid is used it is too often added to a tank full of liquid in pailfuls without making any test of the proper quantity required.

Lime is best employed in the form of milk of lime, which should be prepared in a special apparatus such as is shown in Fig. 53. Lime sufficient for a day's use is placed in the cask, water is turned on until it overflows, and the paddles are kept constantly revolving. The amount of milk of lime overflowing can be regulated with considerable nicety by varying the rate at which water enters the cask, and this is found to be a great advantage in mills where the waste waters vary greatly in volume or character, and especially where they are at times acid in reaction. By increasing the flow of water into the lime mixer at such times a full dose of the milk of lime is added to the acid refuse.

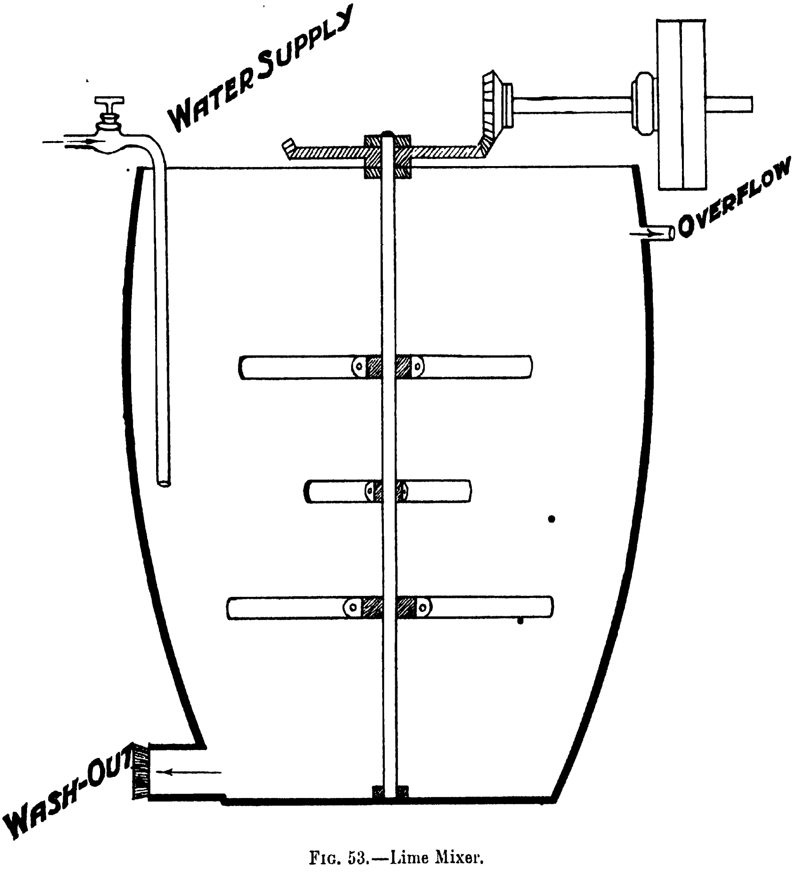


FIG. 53.—Lime Mixer.

The same apparatus can be used for adding alumino-ferric or copperas in solution, but in that case the overflow pipe should be brought up from the bottom of the cask. In that case, too, the solution of the precipitant must be aided by the use of steam or hot water.

There are many other contrivances for adding precipitants in liquid form either in proportion to the flow of refuse at the time, or in continuously regular quantities. One such has already been described in connection with Waite's apparatus (see p. 133). Another quite different form is that used by Lassen and Hjort in connection with their water softeners. The same apparatus can, as already mentioned (see p. 244), be used both for measuring the flow and for regulating the amount of precipitant. The refuse to be treated is discharged from a pipe into one compartment of a double tipper, and when this is full the tipper falls over and receives the refuse in the other compartment. The axle of the tipper is continued into the tank containing the liquid precipitant, and there actuates a valve in the bottom of the tank, which opens with each movement of the tipper sufficiently to allow the proper dose of precipitant to escape. On this axle metal paddles are also fixed which serve to keep the liquid precipitant constantly agitated. As above suggested, the axle of the tipper may at the same time be made to record the number of discharges by an ordinary form of ratchet movement.

In works where the refuse must be pumped it is an easy matter, by the use of a subsidiary pump worked off the shafting of the main pump, such as is mentioned on p. 144, to ensure that the precipitant is added in proportion to the amount of liquid raised.

In works where the tanks are in the form of a tower the labour of carrying the precipitants to the top of the tower can easily be avoided by mixing or dissolving them with water in a tank at the ground level and raising the mixture by means of a chain pump. If this is actuated by a small water-wheel, which in turn is driven by the force of the refuse water entering the tower, the amount of precipitant raised will be in proportion to the flow of the refuse, and this method has recently been adopted by Mr Mackey in connection with his plant described on p. 139.

Another apparatus for adding dissolved precipitants in regular and measured quantities is shown in Fig. 54, as in use at Wakefield Sewage Works for adding a solution of ferric sulphate to the sewage. The precipitant in solution is run into a feed tank in which it is kept at a fixed head, for example, by governing the inlet with a ball valve. From this tank it is fed into one of three glass cylinders. Each cylinder is provided with a restricted outlet, and when the liquid it contains stands at a known level, the amount escaping from the orifice can be ascertained by actual measurement. So long, therefore, as the level of the liquid in the cylinder is kept constant, a known and regular amount of precipitant is escaping, and this constant head can be maintained by regulating the tap on the outlet from the feed tank. Each cylinder has three marks, at which levels the amounts of precipitant discharged are in the proportion of 1, 2, and 3, and by using the cylinders separately or together the rate of flow of the precipitant can be regulated with great exactness.

An ingenious method of adding liquid precipitants in direct proportion to the flow of the liquid treated has recently been introduced by G. Kent, Ltd. (see *Journ. Soc. Dyers and Colorists*, March 1912, p. 108). The apparatus has the advantage that it can also be adapted for the registration of the flow of the liquid. Fig. 55 shows the apparatus, to which the patent name of Tiltometer has been given. The crude waste water flows through a Venturi tube, which is a pipe throttled to take advantage of the principle that the velocity of the liquid in passing through the throat or restricted part of the tube is increased and the pressure proportionately diminished. The upstream and throat portions of the tube are separately connected to pipes containing floats, which are connected one to either end of a tilting beam; the beam in its turn operates a tilting tank in which a constant level is maintained by a ball cock, the outlet of the tank being furnished with an adjustable orifice on a projecting arm. The working of the apparatus is as follows:—As the crude waste water flows through the Venturi a difference of level corresponding to the rate of flow is produced in the float pipes, and this causes the tank to tilt, with the result that the end of the projecting arm is lowered to a distance below the constant level of the precipitating reagent in the tank, exactly proportionate to the rate of flow of the crude waste water in the Venturi tube. This allows the reagent to escape from the tank in proportion to the rate of flow, and by adjusting the orifice the dose of precipitant may be increased or decreased as desired. The precipitant flows into a funnel, from which it is led to the mixing tank. The price of the Tiltometer

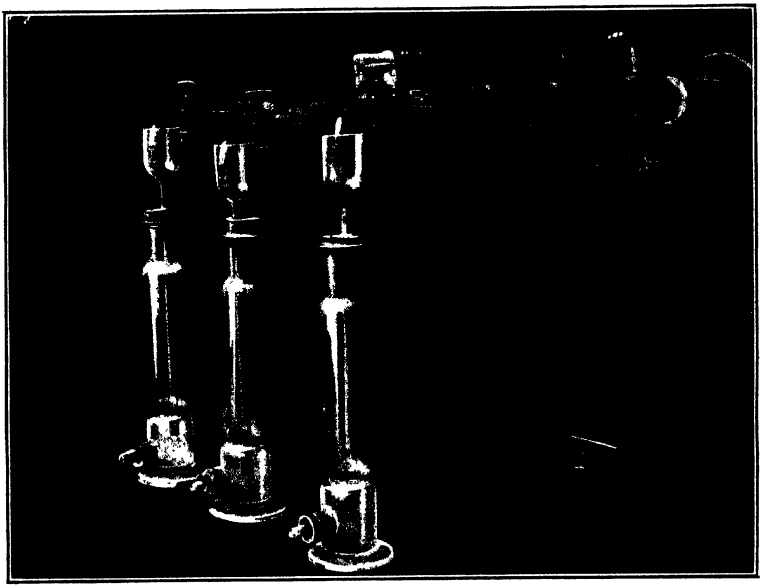


FIG. 54.—Apparatus for adding Liquid Precipitants.

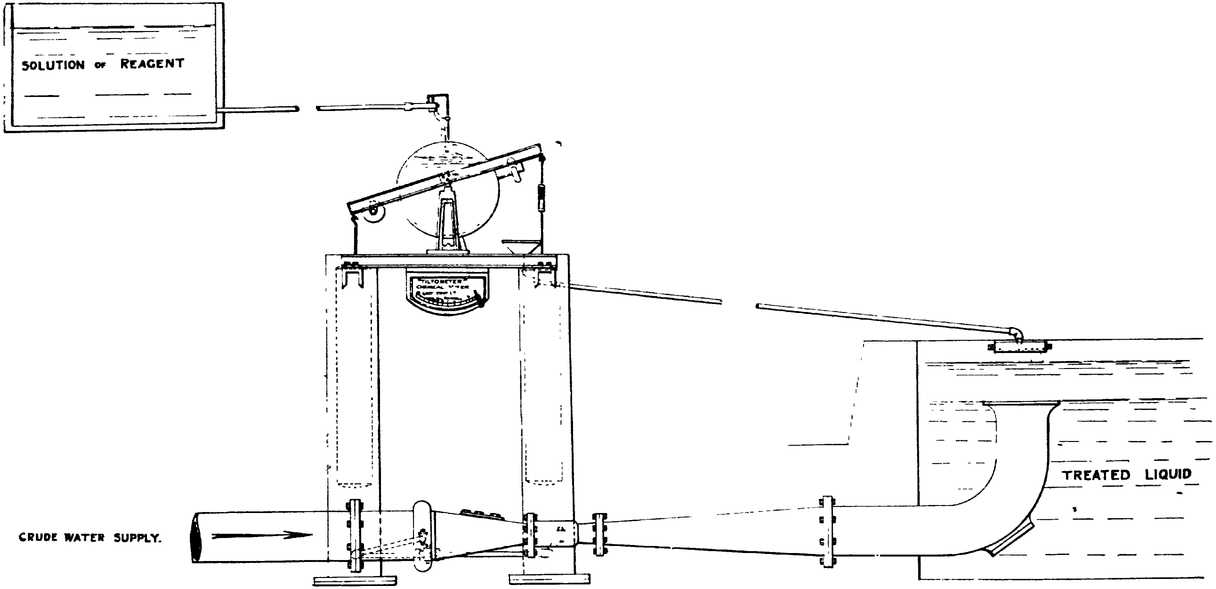


Fig. 55.—Kent's Tiltometer for adding Liquid Precipitants.

for flows of refuse between 1000 and 10,000 gallons per hour is from £80 to £100.

Sludge Treatment.—Sludge, as it is discharged from any kind of settling tank, always contains a large proportion of water; in some cases, as has been mentioned, more than 95 per cent., and at the best seldom less than 80 per cent. In this condition it is a semi-liquid sloppy material exceedingly difficult to handle, and as in most cases it has to be finally disposed of at some little distance from the purification works, it is usually necessary to dry off the moisture so as to bring the sludge into a condition in which it can be removed by spade and cart. This drying also diminishes the weight of material to be removed, for, as pointed out on p. 248, when the moisture in a sludge is reduced, say from 90 to 70 per cent., the weight is reduced to one-third.

Burying in Trenches.—When sufficient area of land is available it is quite possible to deal economically with the wet sludge by burying it in trenches in the ground, and, in fact, this method is one of the cheapest that can be employed.

The disposal of sewage sludge in this manner has been described in the Fifth Report of the Royal Commission on Sewage Disposal, 1898 (p. 171), where also estimates of the cost are given. The method has now been in use for over three years at Wakefield Sewage Works, where the sludge has been largely produced from the treatment of trade refuse. The soil in which the sludge is there buried is about as unsuitable as can be imagined, and yet the sludge has been disposed of with very little trouble, and as the cost has been carefully ascertained, some description and details of the method as there practised may be useful.

Parallel trenches are dug in the soil, the excavations being 3 feet wide and 1½ feet deep, with a space of 5 feet between, upon which the excavated soil is piled up. The trenches are dug some time before they are required, as it is found that the soil, which is a stiff clay, absorbs moisture from the sludge more easily after being weathered. The sludge is run by gravitation from the settling tanks, where it has been precipitated by lime and ferric sulphate, into a sludge well, and thence is pumped into an iron main, through which it is distributed to the trenches. These are filled to a depth of 2 feet, and after most of the water has percolated away or evaporated they are again filled with sludge to the same level, and this process is sometimes repeated a third time. The sludge is allowed to dry for some time (generally about three weeks in ordinary weather), and the soil between the trenches is then filled in until the land is level again. A plan and section of the trenches are given in Fig. 56. A new trench can be dug in the 5-foot interval between the original trenches, and a further amount of sludge deposited there, and after a sufficient time has elapsed for the sludge to consolidate and become partly incorporated with the soil, the process can be repeated over the whole area.

At Wakefield, the cost of making and filling the trenches amounts to

4d. per linear yard of trench, and as the trenches are filled 2 feet deep with sludge, this amounts to 6d. per cubic yard of wet sludge if only one dose of sludge is applied, but if three doses are applied, as described above, the cost would not be much more than half this amount. The area of land required for this method of disposal is given in the Report of the Royal Commission as between 1 and 3 acres per 1000 tons of wet sludge, according to the porosity of the soil. It is, however, not often that sufficient land for the adoption of the above method is available on a manufacturer's premises.

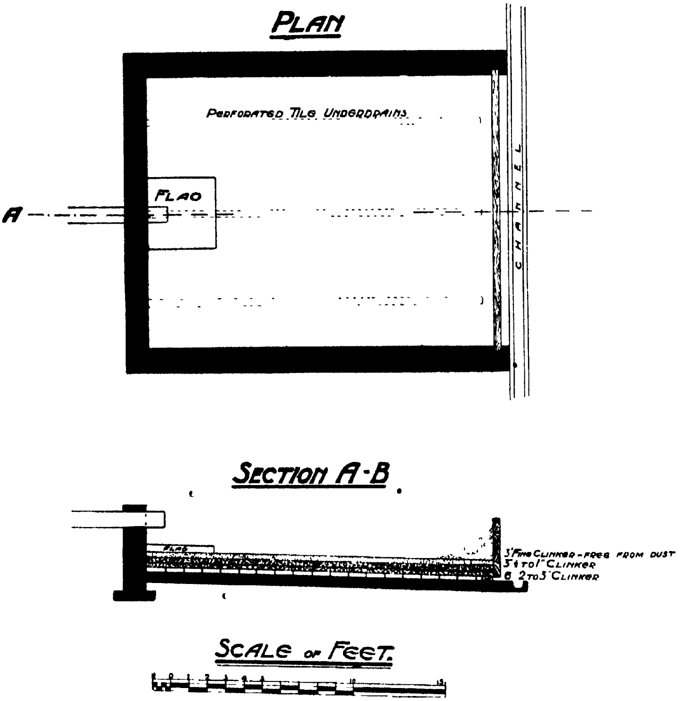


Fig. 57.—Sludge Filter.

Drying on Sludge Filters.—The commonest method of drying the sludge is by running it on to a sludge filter where the moisture can easily drain away, and the construction of such a filter is an important matter, inasmuch as with an imperfect filter the period required for drying the sludge may extend over months, whereas if the filter is carefully made less than a week may suffice.

In one form of construction (see Fig. 57) the filters are built in bays, each bay having brick walls round three sides and a concrete bottom, which slopes with a good gradient towards the fourth side. This fourth side is closed by wooden battens sliding in grooves in the brickwork. On the floor of the filter three lines of perforated pipe drains are laid, and on these is placed the filtering material of engine clinker, varying from pieces 2 to 3 inches in size at the bottom to fine clinker freed from dust at the top, and in all about 18 inches deep. The clinker is heaped up at the back of the wooden battens, so that any liquid escaping must pass through it. Just outside the wooden battens there is a channel in the concrete which receives the liquids draining from the sludge.

This escaping liquid is seldom sufficiently pure to be discharged to a stream, and the purification works should be so arranged that it can be readily returned to the settling tanks to be purified along with the crude refuse. This is an easy matter where the crude refuse is received into a pump well and lifted into settling tanks, for in such a case the filters should be so placed that they will drain into the well. In other cases the settling tanks have to be emptied by pumping, and then the sludge filters can be placed at such a level that they will drain back into the tanks.

Another form of filter is constructed with four brick retaining walls and a concrete floor, the latter sloping from either side to a central channel. This channel is covered by flat stones or tiles, resting on supports which raise them from the surface of the concrete. The under drainage is carried out by covering the whole surface of the concrete with rough stone pitching, such as is used for the foundation of a macadamised road, the stones being laid parallel to the ends of the tank, so that liquids draining away are directed to the central channel. The filtering material consists of engine clinker, arranged as shown in Fig. 58, with a very fine layer, freed from dust, on the surface. In one case the cost of such a filter of 38 square yards in area amounted to £30; in another case a similar filter of 224 square yards area cost £73; the price in both cases including material and labour.

The successful use of this filter, as of the last, depends upon careful management. It is essential in both cases that a sufficient number of filters should be provided, so that at all times some can be out of use for cleaning and resting. The sludge should never be poured on to them to a greater depth than one foot. In a few days, in dry weather, the sludge is sufficiently dry to be removed by spade, and if the removal is carefully done a little of the top layer of fine material is lifted off with the sludge, leaving a surface quite clean and unclogged. A little fresh fine material is sprinkled over the surface and the filter is at once ready for another dose of sludge, although it is better to leave it exposed to the air for at least a week. The advantage of having a filter upon which a charge of sludge can be dealt with once a fortnight need hardly be pointed out, and similar results could be ensured in wet weather by placing a roof over the filters, as, indeed, is often done by manufacturers who have greasy sludge to deal with.

The time taken for the drying of a very liquid sludge can be much shortened by drawing off the supernatant water, which quickly separates after the sludge has been discharged on to a filter. Several forms of decanting valve are on the market, but perhaps the simplest contrivance is to board off one corner of the filter with planks in which 2-inch holes are bored at different levels. These holes are closed by plugs which are removed as the sludge sinks below them, thus allowing supernatant water to escape. This water is generally rather foul, and should in all cases be returned for treatment along with the crude refuse.

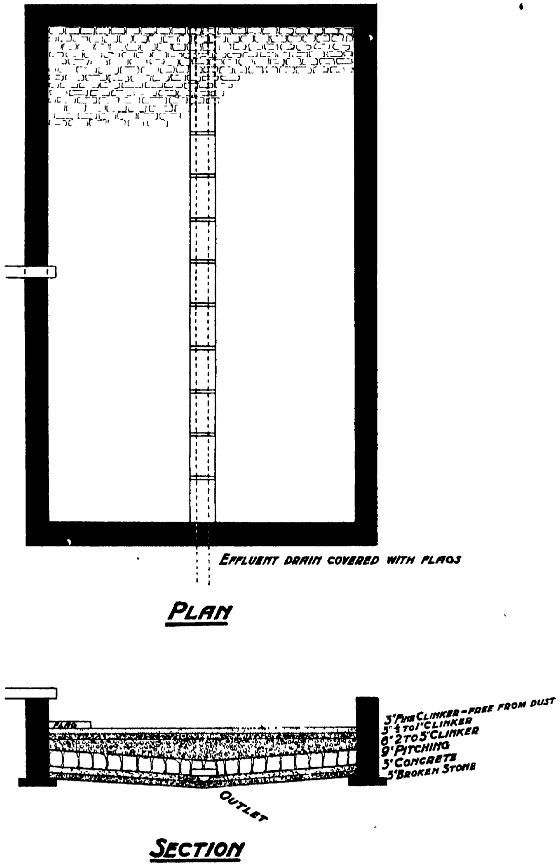


FIG. 58.—Sludge Filter.

Where the sludge produced from trade refuse has a manurial value, and where there are stables upon the manufacturer's premises, a patent method of sludge disposal which has been adopted at Penrith Sewage Works may be found very useful. The sludge at Penrith is very liquid, being forced from the settling tanks by hydraulic head. For its reception four beds have been provided, similar to those in Fig. 57, with concrete bottoms and brick walls round three sides. In these beds a layer of straw or stable litter is placed some 6 inches thick, and this is covered by a layer of liquid sludge; then another layer of litter is laid, followed again by a covering of liquid sludge, and the process is repeated until the bed is full. At the open end of the bed the litter and sludge are kept in place by battens. The bottom of the bed is freely under-drained by means of perforated half-pipes placed on the concrete floor, and from these a number of perforated upright pipes are brought up to the surface for drainage and aeration. By this arrangement the water escapes rapidly from the sludge, filtering through the straw, and in a very short time the whole contents of the bed are consolidated into a mass which is easily dug out to be carted away. The straw used is partly litter from the Urban District Council's stables, partly straw got from a farmer in exchange for grass from the sewage works, and partly litter from adjoining private stables. Each of the beds is emptied about once in six weeks, and there is no difficulty in selling the contents to farmers at 1s. 6d. per load.

By treatment upon filters such as those described above the moisture in a sludge can be reduced to 75 per cent., and the sludge thus dried is brought into a condition in which it can be easily carted away. By referring to Fig. 47 it can be calculated how very greatly this drying reduces the weight of material to be removed.

Sludge Pressing.—Where a sludge consists of very fine particles such as the fuller's earth from blanket scouring, it is very retentive of moisture and very difficult to dry in any ordinary sludge filter. In such a case it may be advisable to press the sludge in a press similar to that used at sewage works, described in all text-books on sewage, and made in various forms by Messrs Manlove, Alliott & Co., Nottingham; S. H. Johnson & Co., Ltd., London; John Wilson & Son (Johnstone), Ltd., Johnstone, N.B., and numerous other firms.

It is often found advantageous to settle a liquid sludge and remove the supernatant water before it is passed into a filter press, as has been described above in dealing with sludge on sludge filters. By doing this the moisture in the sludge may be reduced from 95 to 85 per cent., and the amount of sludge to be pressed to one-third. It is frequently found that the addition of 1 per cent. of lime to a sludge enables it to be pressed much more rapidly and perfectly, as the lime forms insoluble soaps with any fatty matter present and acts upon the fine suspended solids so that they lose their retentiveness of moisture. By pressing, the moisture in a sludge may be reduced to something under 60 per cent., and the cake produced is easily handled. The Royal Commission, 1898, in their Fifth Report (p. 170), give the total cost of sludge pressing, including lime, fuel, labour, press cloths and repairs, and also interest and sinking fund, as between 2s. 9d. and 3s. 9d. per ton of press cake produced, containing 55 per cent. water, or between 7·3d. and 8·7d. per ton wet sludge, containing 90 per cent water; but at Leeds, as already mentioned (p. 119), the cost, without including interest and sinking fund, only amounts to 1s. 8d. per ton of press cake.

In drying sewage sludge great attention has recently been paid to the use of centrifugal machines, but for the most part these are more costly and less efficacious than sludge presses. The new centrifugal drier, however, described on p. 230, appears much simpler in construction and easier to manipulate than any previously on the market, and is likely to be found very useful in dealing with sludge.

The sludge produced from trade refuse and dried as described is, generally speaking, a useless material. In some cases it may contain a sufficient amount (say 15 per cent.) of grease to be worth recovery by a solvent process; in other cases the nitrogenous organic matters present may make the sludge useful as a manure; or the vegetable matters present may be sufficient to give the sludge a calorific value; but most often the sludge must be tipped upon a waste heap or used to fill up hollows or old quarries.

The quantity of sludge likely to be produced from a trade refuse can be roughly estimated by ascertaining the amount of suspended matter present, bearing in mind that the weight of sludge containing 90 per cent. moisture is ten times the weight of the dry solids it contains. Thus, for example, from the analyses in Table LXXIV. it can be calculated that, in the samples there referred to, a ton of wet sludge containing 90 per cent. moisture may be expected from 400 gallons of coal-washing refuse, 7000 gallons of piece-scouring refuse, 10,000 gallons of tannery refuse or dyewater, 27,500 gallons of brewery refuse, or from 40,000 gallons of papermakers' refuse.

Taking into account the volume of waste water produced in any of these trades, it will at once be evident what enormous amounts of sludge are discharged when the crude refuse is permitted to enter the streams. Indeed, no manufacturer can beforehand be made to appreciate the amount contained in his waste waters, and in a very large number of cases the quantity of sludge actually produced has opened his eyes to the great waste of valuable materials which has been going on unnoticed. The saving he has in consequence been able to effect has often gone far to repay him for the cost he has incurred for the purification of his refuse, or has even yielded a considerable profit. Instances of this have already been given in the wool, coal, and paper trades.

Straining Filters.—In most cases it is inadvisable to depend for the purification of trade refuse on precipitation or settlement alone. The tank effluent generally requires filtration, and in all cases this is desirable as a safeguard against the escape of floating or suspended matters. In many cases it is sufficient to pass the tank effluent through a straining filter, and this can be constructed like the sludge filter shown in Fig. 58.

Filters soon become clogged by the suspended matters arrested upon the surface and should then be dried off so that the coating of mud can be removed. It is necessary, therefore, that they should be made at least in duplicate, so that one can be resting while the other is in use.

Filters of this kind are in common use at waterworks, but in that case sand is the medium usually employed and is, generally speaking, too fine for straining trade effluents, as the suspended matters they contain are greater in quantity and would soon choke the sand. Filters for straining trade effluents are much oftener constructed of well-graded clinker.

In place of ordinary sand filters there are many mechanical high-pressure filters used for water purification, and some of these, such as those of Bell Bros. (Fig. 25), Candy, Royles, and Mather and Platt, can be adapted for the efficient removal of suspended matter from tank effluents. These have the advantage, which has been described in the case of Bell's filter, that they can be automatically cleansed. Another filter possessing this advantage is the Wilson filter, which has already been described in dealing with the refuse from the paper trade (p. 88).

Biological Filters.—In suggesting methods of purification for waste waters containing organic matter in solution, mention has repeatedly been made of biological filters. These have now come into common use for the purification of sewage, and detailed descriptions of their construction and working can be found in any of the text-books on sewage, such as those of Dibdin (p. 88), Moore and Silcock (p. 629), Raikes (p. 222), Dunbar (p. 187), and Kershaw (p. 254). See also p. 64.

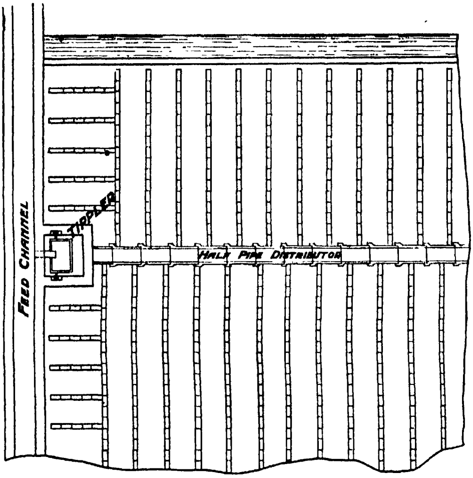
Percolating Filters.—In selecting a method of construction and the needful distributing apparatus for a filter for the purification of trade refuse, regard must be had to the ordinary working of the filter in the hands of an employee of the manufacturer. The scheme adopted must not be too costly; the apparatus must be as simple as possible; the works must be nearly automatic in action and must require a minimum of attention. Success will be found to depend in the first place on the adequacy of the means adopted, secondly on the attention given to the details of construction, and thirdly on the care taken to keep the works in good order.

The size of the filter must depend upon the quantity of liquid to be dealt with and upon the amount of polluting matter it contains, and in making the necessary calculations it must be borne in mind that usually the discharge of trade refuse occurs only during the working hours of the day. For a rough guide it may be said that at the least a cubic yard of filter must be allowed for every 50 gallons per day of a strong, well-settled liquor, or for every 100 gallons of a weaker precipitated liquor.

It will rarely be practicable to deal with crude refuse upon a biological filter. The suspended matters must generally first be removed in settling tanks, and it will often be advantageous to use chemicals to neutralise undue acidity or alkalinity, or to bring some of the dissolved matters out of solution so as to retain them as sludge in the settling tanks. As a general rule no attempt should be made to filter a liquid until the suspended solids have been reduced below 10 parts per 100,000.

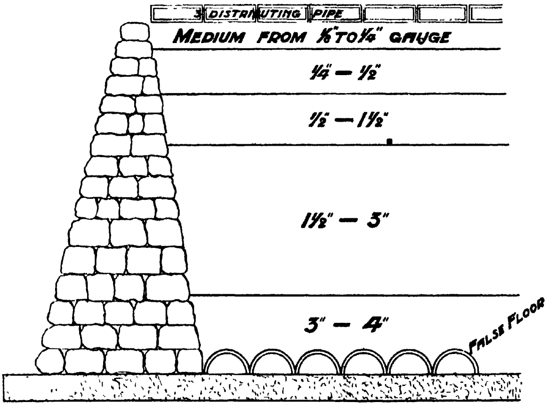
The ordinary apparatus for distribution on such a filter by means of rotating sprinklers or jets is somewhat costly to install and requires a good deal of attention. A simple method of distribution, which has been found effective both on a small scale and when dealing with large amounts, has been brought into use for dealing both with sewage and trade refuse, and a description of a filter thus equipped may be found of service. The floor of the filter should be of some impervious material, preferably of concrete, and should be laid with a considerable slope to an outfall channel, which should run along one side of the filter. A false floor should be provided and may be constructed of slates or flat tiles supported on rows of bricks set 6 inches apart, or, better still, of specially made half-pipes or square tiles on feet, such as those of Naylor Brothers, Denby Dale, or Stiff & Co., Birmingham. It is not absolutely necessary to provide a false floor, but when this is omitted special care must be taken to have the bottom layer of filtering material in large pieces, so as to permit of the escape of finely divided solids with the effluent. Instead of the false floor a layer of stone, arranged in the same way as is usual in making the foundation of a road, may be laid on the concrete floor (see Fig. 58). In any case care should be taken to arrange matters so as to facilitate the free escape of the effluent, with its suspended solids, to the outfall channel. When the filter stands above ground the walls may be of brickwork, of stone and mortar, or of dry rubble, slag, or clinker. If put together without mortar they should be built vertical on the inside, and with a batter of one in three on the outside, as in winter the liquid in the outer portion of the filter is liable to freeze and thrust the wall outwards. If the space available is limited, and a vertical dry rubble wall is preferred, it can be strengthened sufficiently by using vertical wood battens placed 18 inches apart on the outside of the wall and binding them together with strong wire. There is no necessity for the filter to stand above ground; it is rather advisable to have it under ground level, as it is then hidden from sight and protected to a great extent from frosty winds, but when sunk in the ground it should be constructed with the side towards the outlet channel free, so that air can easily enter both by the false floor and through the wall on that side. If the false floor is well made there is no necessity to have pervious walls. In fact, solid walls are an advantage in that they minimise the danger of nuisance from flies, which are apt to breed in the crevices of a dry wall. The shape of the filter is immaterial and will depend upon the available site.

The filtering medium used may be of any resisting material, such as broken stone, gravel, slag, or clinker—such a substance, in fact, as will not readily break down under the alternate wetting and drying to which it is subjected. The depth of the filter is also immaterial, but preferably should not be less than 3 feet nor more than 6 feet. The full effect of such a



PLAN

SCALE OF FEET.



SECTION

SCALE OF FEET.

FIG. 59.—Percolating Filter.

filter cannot be obtained until the medium has become "ripened" by the growth of the purifying organisms on it, and in dealing with some kinds of trade refuse it is desirable to incorporate in the top layer of the filter some medium from a filter which has been in use at sewage works, or to dose the filter for some time with weak sewage, or urine from stables or cowsheds, before it is brought into use for dealing with trade refuse. Such a preliminary treatment of the filter is especially to be recommended when the trade refuse consists of liquids which have been rendered sterile by boiling, such, for instance, as spent gas liquor (see p. 33), distillery refuse, or waste dyewaters.

The most important point is the proper filling of the filter, and the medium must be graded with great care. In a filter 6 feet in depth (see Fig. 59), the first layer in the bottom, on the false floor, should consist of hand-picked pieces 3 to 4 inches in diameter, to the depth of 6 inches; above this should come a 3-foot layer consisting of pieces between 3 inches and $1\frac{1}{2}$ inch in size; then a 12-inch layer of material which has passed through a $1\frac{1}{2}$-inch riddle and has been kept back by a $\frac{1}{2}$-inch riddle; followed by a 6-inch layer of sizes from $\frac{1}{2}$ inch to $\frac{1}{4}$ inch; and finally on the surface there should be a 12-inch layer of fine material composed of particles which have passed through $\frac{1}{4}$-inch mesh and been retained by a mesh of $\frac{1}{8}$ inch. A filter of 3 feet depth should be constructed like the upper 3 feet of the above. The surface layer of fine material should be banked round the sides of the filter to a height of 3 inches or so above the general level, and to a width of 6 inches within the external wall, so as to prevent any liquid overflowing.

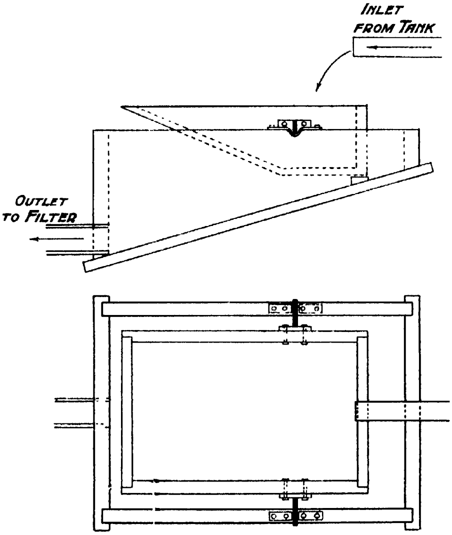


FIG. 60.—Wooden Tipper.

A tank effluent, if passed on to the surface of such a filter directly and continuously, will sink at once through the material and only reach the parts more distant from the inlet after the filter surface has become partially clogged. To obviate this the tank effluent must be applied in flushes, and this object is attained by the use of special apparatus. The simplest form of this apparatus is a tipper such as is supplied by Messrs. Ham Baker & Co., Ltd., Westminster; Messrs. Tuke & Bell, Ltd., 69 Leadenhall Street, London, E.C.; and Mr W. E. Farrer, Cambridge Street, Birmingham; but for a small installation one can be made of creosoted wood by any village carpenter (see Fig. 60). The capacity of the tipper should be according to the flow of refuse and area of filter. For a filter of 100 square yards in area, and a flow of 400 gallons an hour, a tipper of 20 gallons would be required, and this would give at each discharge a quantity of $\frac{1}{5}$ gallon of liquid per square yard of filter. These tippers are sometimes made in a double form (see Fig. 61), so that if placed across the middle of a filter they discharge first on one side and then on the other, and a double tipper, each half of which holds 10 gallons, is preferable to one so large as 20 gallons in capacity. It is not advisable to have a single tipper of a capacity greater than 20 gallons, or discharging oftener than twenty times an hour: that is, dealing with a flow greater than 400 gallons an hour: and when the flow is larger than this, it must be divided between two or more tippers. As an apparatus like this is liable to be affected by frost, the tipper may require to be protected by a wooden cover, or, where the circumstances are suitable, may be placed underground in a manhole. Other forms of apparatus for discharging the tank effluent in flushes, which can be used in suitable cases are supplied by Messrs Adams, Ltd., Ames Crosta, Ham Baker & Co., Ltd., Mather & Platt, Ltd., or Tuke & Bell, Ltd.

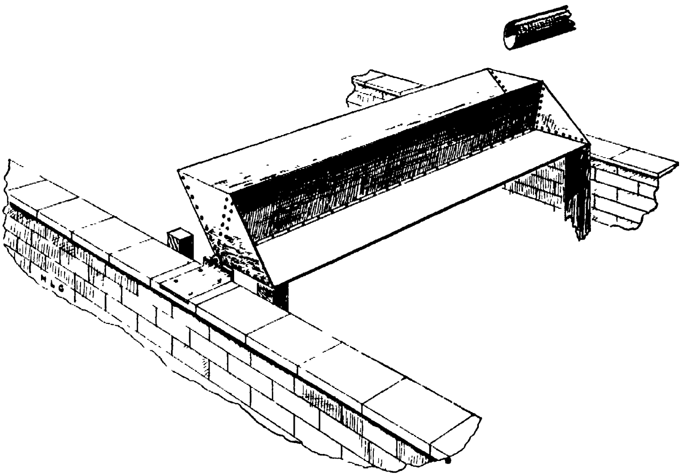


FIG. 61.—Double Tipper.

The better to ensure the distribution of the liquid over the whole of the filter, it is necessary to provide special channels to convey it to all parts of the surface, and this can best be done by laying a series of level drains of ordinary butt-jointed field pipes in herring-bone fashion upon the surface; or, better still, glazed pipes of the same shape, for the field pipes are very liable to be injured by frost. Into these pipe channels the tank effluent is discharged in intermittent flushes, and the liquid is distributed over the whole of the filter, a little escaping by every joint in the pipes. Each discharge is thus absorbed by the top layer of fine material, which takes it up like a sponge and gives it out slowly from the under surface to percolate gradually throughout the whole body of the filter. By the provision of valves or plugs on the distributing pipes the liquid can be kept off any part of the filter which may require to be rested or cleansed.

A filter such as the above, complete in every respect, costs approximately ten shillings per cubic yard.

In the effluent from a filter of this kind, there is at times a considerable quantity of humus or fine suspended solids, and these should be removed either by passing the effluent through a small settling tank, having a capacity equal to two hours' flow, or through a shallow filter of 3 or 4 inches of sand lying upon 6 inches of gravel, or, better still, over a small area of grass land. The liquid as it comes from the percolating filter is generally free from offensive matters, and will greatly stimulate the growth of grass.

The surface of the filter will from time to time need to be scraped to remove any sludge or grease, and when this is done a little fresh material, similar to that forming the surface layer, should be added to keep the filter to its original depth, and the opportunity should be taken to adjust the drain pipes to the proper level. With slight attention the filter should be practically permanent.

Slate Beds and Contact Beds.—Another biological method of purification is by means of the slate beds or contact beds of Mr Dibdin, such as are very often used for the purification of domestic sewage. They are seldom to be recommended for the purification of trade refuse, except that the slate beds may be found useful in the purification of liquids containing large quantities of animal matter, such as the refuse from glue manufacture or tripe boiling, for they are effective in reducing the offensive smells that these liquids are liable to evolve. It may here suffice to refer to the description of them in Mr Dibdin's writings.

Land Treatment.—In place of a straining or biological filter it may sometimes be preferable to pass a tank effluent over land, and where there is a sufficient area of suitable land it is better than any filter. Quite as much care as in the case of a filter is, however, necessary to ensure proper distribution of the liquid over the surface, and due attention must be given to changing the area under irrigation at short intervals, or the surface will become choked and "sick."

If the area is sufficient and there is a good covering of grass on the soil it is usually better to adopt broad irrigation, but if the area is restricted and the soil is not too porous, intermittent downward filtration may be resorted to, dividing the land into plots of suitable size and flooding these in turn. In this case the plots should, from time to time, be cleansed of deposited solids and thoroughly tilled. In deciding the area of land necessary for the treatment of a liquid, regard must be paid to the nature of the soil and to the character of the liquid, especially to the amount of suspended solids. The Local Government Board say that in dealing with sewage the maximum quantity of liquid which can be dealt with on the best soil is 30,000 gallons per acre per day.

Evaporators and Incinerators.—It has several times been suggested, for instance in connection with wool-washing suds and the kier liquors from paper works and bleach works, that it may be advantageous to get rid of these liquids by evaporation. The simplest method of doing this is to boil the liquid in an open vessel, but, as the utmost that can be expected from this process is the evaporation of some 8 lbs. of water per pound of coal used as fuel, it will be found an expensive proceeding. It is used at some of the blast furnaces in Lanarkshire for evaporating spent gas liquor, but there enormous quantities of waste gas are available. The evaporation of a similar liquid in the specially constructed gas furnace shown in Fig. 4 is a distinct advance upon the foregoing method. As will be readily imagined, the distribution of the liquid in the furnace in the form of a spray considerably aids vaporisation.

The same effect is aimed at in the Porion evaporator, which is in use for spent gas liquor at the Dalmellington Ironworks, Ayrshire, and also for the kier liquor from the boiling of esparto grass at the Rishton Paper Mill of Messrs A. M. Peebles & Son, Ltd. A plan and section of this evaporator is shown in Fig. 62. In this figure it will be seen that in addition to the evaporating chamber K, there is an incineration chamber *b*, the two being separated by a combustion chamber *c*. The liquor to be evaporated is run into a flat pan *z*, over the combustion chamber where it becomes heated nearly to boiling point. It is allowed to run from this pan in a regular flow into the evaporation chamber K, where two paddles, *i*, are kept constantly revolving, dipping at each revolution into the liquid so as to throw it up in a fine spray. Through this spray the hot gases from the incinerating chamber *b*, and the combustion chamber *c*, pass on their way to the chimney J. When the liquid is sufficiently concentrated by this evaporation it is run into the incinerating chamber *b*, where the flames of the furnace *a* play upon it and complete the evaporation, finally igniting the combustible matter in the dry residue. Owing to the presence of so much moisture in the contents of the incinerator *b*, the combustion is by no means complete, and for this reason a special combustion chamber *c* is introduced, where the combustion process is completed by the aid of burning fuel.

The apparatus is very fully described by Mr Davies in a paper read before the Scotch Paper Makers' Association in November 1888, and quoted by W. Naylor, F.C.S., in his book on *Trades' Waste.* Mr Davies says that for dealing with paper makers' lye at 10° Tw. (1·050 specific gravity), a Porion evaporator is by far the best, but suggests that liquids weaker than this should first be concentrated to the above strength by other means. He states that in the evaporation chamber 11½ lbs. of water may be evaporated per pound of fuel, and in addition 8 lbs. of water for every pound of dry organic matter burned in the incineration of the dried solids obtained from the liquid itself.

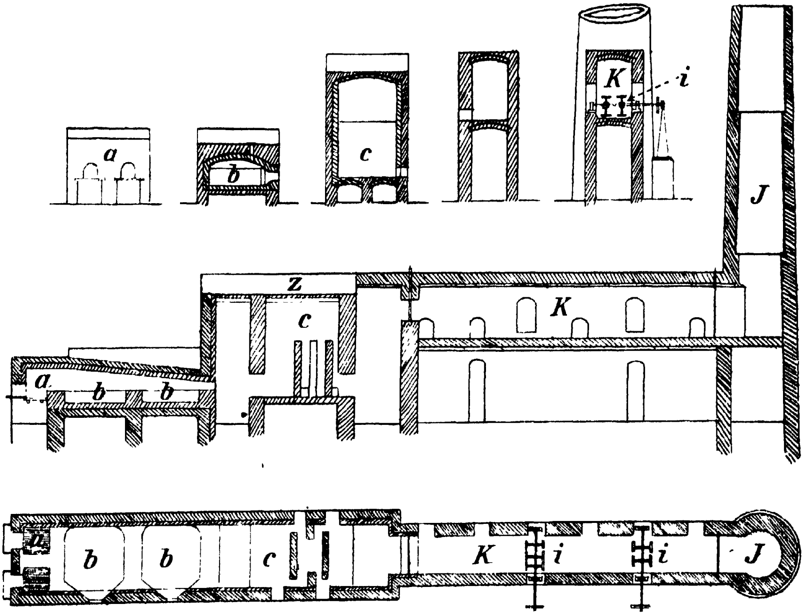


Fig. 62.—Porion Evaporator. (From Naylor's *Trades' Waste.*)

It has been stated that the exposure of a liquid to heat in the form of a fine spray considerably lessens the amount of fuel required to evaporate it, and this amount can be reduced still further by boiling the liquid at a lower temperature. This is effected by using a vacuum pan, in which by means of an exhauster the pressure on the liquid is reduced. This form of evaporator is quite commonly used in many trades, for instance in sugar boiling, and in making extracts of vegetable substances. Such pans are made by many firms, as, for instance, Messrs George Scott & Son, London, the Mirrlees Watson Co., Ltd., Glasgow, and the Kestner Evaporator and Engineering Co., Ltd., London.

By an ingenious application of this principle a "multiple effect" can be produced by utilising the heat contained in the vapours arising from one evaporation of the liquid to boil the latter again at a lower pressure; and apparatus constructed for this purpose is made by the three foregoing firms.

Scott's multiple effect evaporator consists of a series of vessels (Fig. 63), into the first of which the liquid to be evaporated is admitted at the bottom and flows upwards through a series of vertical pipes, surrounded by a steam jacket, into the evaporation chamber. The liquid is thus caused to boil and the vapour passes into the steam jacket of the second vessel. The partially concentrated liquor is allowed to flow from the first vessel into the bottom of the second vessel, where it is further evaporated in the same way but at a lower pressure, and this process is repeated in the remaining vessels at successively reduced pressures. The necessary vacuum in the various vessels is maintained by means of a pump and surface condenser attached to the evaporation chamber of the last vessel.

It is impossible within the limits of a treatise such as this to give any detailed explanation of the method of working a Yaryan evaporator, but Fig. 64 will give some idea of the apparatus. The evaporator shown is threefold, the same process being repeated three times at successively lower temperature and pressure, and each section (see No. I.) consists of a heater T, an evaporating chamber A, and a separator D, where the vapour is separated from the liquid being concentrated. A condenser and vacuum pump, not shown in the illustration, are placed at the end of the series.

The topmost chamber A is heated by steam from an ordinary boiler, and the liquor, previously warmed in the heater T (as will be explained), passes through a coil of tubes B within the chamber and surrounded by the steam, and is made to boil. The coil of tubes B is continued into the separator D, in which the pressure is reduced, and there the steam which has been generated separates from the liquor, which is thus to this extent concentrated.

The process in the next section (No. II.) is the same, except that the steam used for heating the chamber F is not here obtained from the boiler, but is the steam from the liquor separated in the first separator D; the liquid in the interior of the coils G is the already partially concentrated liquor from the first separator D; and the pressure in the second separator J is again lower.

The concentrated liquid is passed through the third section and treated in the same way, the steam from the previous evaporation being used to heat it, the pressure in the separator being less than that of the atmosphere, and the vapour from the last separator being condensed by an ordinary condenser.

The liquor which is being evaporated is passed upwards through the three heaters and reaches the topmost chamber A at or near boiling point, by being in each carried through a series of coils, R, S, T, which are

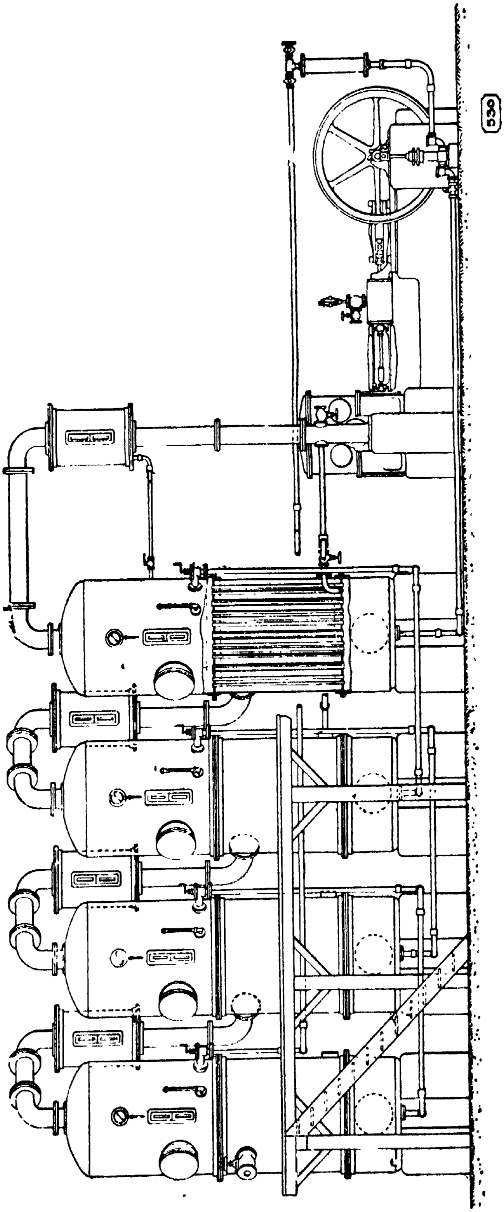


Fig. 63.—Scott's Multiple Effect Evaporator.

heated externally by the condensed water from the chambers A, F, and L. This condensed water finally runs to a tank where it is stored for use.

The passage of the liquor through the apparatus is brought about by the action of a vacuum pump, the pressure in the various separators being regulated once for all by the adjustment of certain valves on the connecting pipes.

By this multiple effect apparatus the concentration of the liquid can be continued to any desired extent, and the evaporated water is condensed and can be used for feeding boilers or other purposes.

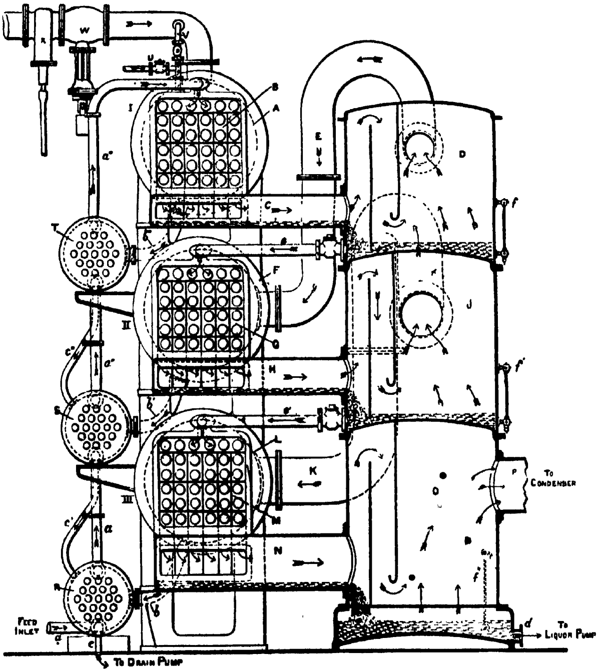


FIG. 64.—Yaryan Triple Effect Evaporator.

The Kestner evaporator, as will be seen from Fig. 65, is somewhat simpler in construction. Each section consists essentially of a tube about 20 feet long containing a number of pipes, upwards through which the liquid to be concentrated is passed at a slow rate. The tube is heated by steam from a boiler which causes the liquid at the bottom and inside the pipes to boil, and the bubbles of vapour rapidly increase, until at a height of 3 to 6 feet from the bottom they form a continuous stream, causing the liquid to form a film on the inside of the pipe. The speed of this core of vapour is greater than that of the liquid, and this latter is carried up in a thin film to the top of the pipe, where there is a contrivance for the

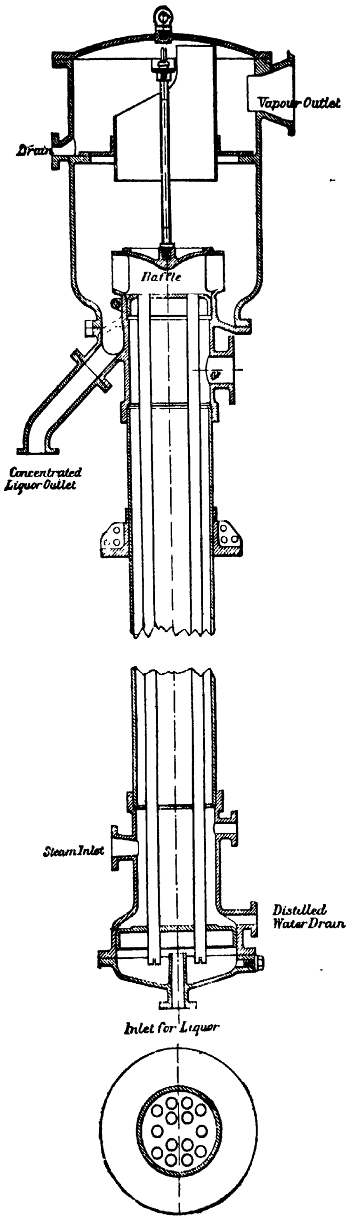


Fig. 65.—Kestner Evaporator.

separation of the steam from the liquid. This steam is used, as in the Yaryan apparatus, for heating a second tube, and in a "multiple effect" apparatus the whole process is repeated several times, the necessary reduction of pressure in the tubes being produced by a condenser and vacuum pump. The Kestner apparatus is rendered much more economical by the adoption of a special boiler (see Fig. 65A), which is fed by the liquor to be evaporated, so that there is no waste of heat in the production of steam in a separate water-fed boiler, but all is used for the concentration of the liquor.

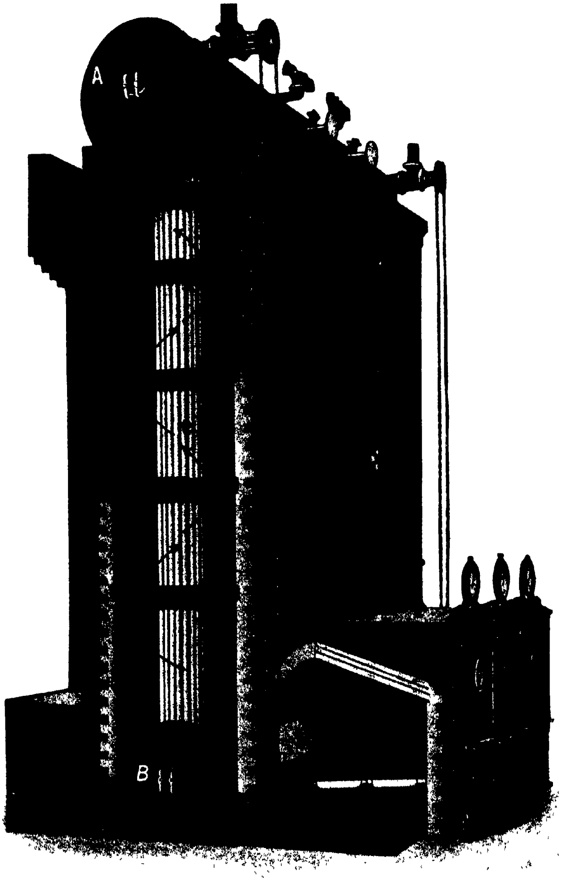


FIG. 65A —Kestner Boiler.

After an evaporation process it is frequently necessary that the residue should be burnt, sometimes for the recovery of some valuable bye-product, as, for instance, the potash salts from wool washing (p. 109), or the soda from kier liquors in the paper trade (p. 88). This may be accomplished either on open hearths, as in the Porion plant (Fig. 62), or in some form of revolving incinerator, such as that made by Ernest Scott & Co., Ltd., London, which is shown in Fig. 66. This latter consists of an iron cylinder lined with fire-brick, which can be made to revolve on a central axis slightly inclined to the horizontal. Under this cylinder at its lower end a furnace is provided, by means of which the interior can be raised to a high temperature, the furnace gases being conducted through the interior of the cylinder. The material to be incinerated is introduced into the upper end of the cylinder in the form of a semi-liquid sludge and, aided by the revolution of the cylinder, falls gradually to the lower end, parting with its moisture to the hot gases as it travels. At the lower and hotter end of the cylinder all the moisture has been evaporated, and the resulting cake or powder catches fire, being thus freed from much of its organic matter, and leaving a crude carbonate of potash or soda behind. This can be lixiviated with water and causticised for re-use as described on p. 88.

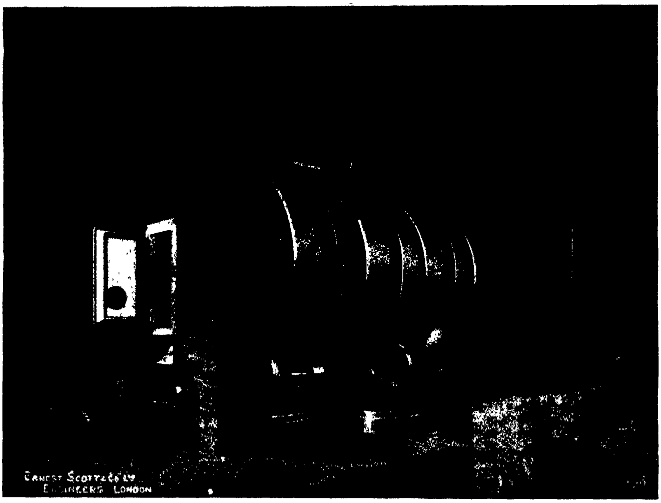


Fig. 66.—Revolving Incinerator.

Conclusion.—In selecting apparatus for the purification of waste waters two things should be particularly borne in mind. The waste waters almost invariably change greatly in character and volume at very short intervals. It is necessary, therefore, to obtain somewhat exact information of the average composition by taking samples at frequent intervals throughout the whole of the working day and mixing these for analysis in volumes proportioned to the rates of flow. It is also necessary to design the plant so that the various discharges are mixed as thoroughly as possible before treatment. In the second place, the manufacturer almost constantly underestimates the volume of his refuse, and it is necessary to estimate carefully the maximum discharge to be expected during any working day, bearing in mind that the discharge usually takes place during ten hours of the twenty-four, although in many cases it may be expected that at times the mill will be working overtime or even continuously. Works must be designed to deal with the maximum flow of refuse during the period of its discharge.

The management of purification works is nearly as important as their adequacy and proper construction. The best of tanks and filters may soon become useless if they are not kept clean and in good order. A scheme which has been designed to include chemical precipitation is not likely to succeed when the precipitants are not added continuously and in proper quantities. The most general cause of failure of properly constructed works is the neglect to remove the sludge at regular intervals, and this should always be carefully attended to. As has already been pointed out, care should always be taken to have a sufficient number of sludge filters, and the tanks and filters should always be so arranged as to make the labour of sludging as light as possible. For this reason tanks of the Dortmund form, or like those of Waite & Mackey, are generally to be preferred, as they can be cleansed of sludge by simply opening a valve.

Above all, it is not to be expected that any purification works will be successful unless the manufacturer himself takes an intelligent interest in their construction and management.

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CHAPTER XII.

DISCHARGE OF TRADE WASTE WATERS TO PUBLIC SEWERS.

Recommendations of earlier Royal Commissions—General law on the subject—Legal decisions—Local Acts of Parliament—Third Report of the Royal Commission on Sewage Disposal, 1898—Local Acts based on this Report—Procedure of local authorities—Comparison of ordinary domestic sewage and crude trade refuse—Regulations and agreements—Preliminary treatment required—Liability of manufacturer for pollution—Bibliography.

In the foregoing chapters it has been proved that for a manufacturer who discharges his trade waste water into a stream there are means available for purifying it so that it will have no harmful effect. It has been shown that although in some cases he may find the purification process profitable, in the majority it will entail on him no inconsiderable outlay for the construction of works and a constant expense for their upkeep.

There is, however, generally an alternative course which he may follow, for if a public sewer is available it may be possible for him to come to terms with the Sanitary Authority for the reception and treatment of his trade refuse. In the interest of the purity of the streams this is indeed the better course to adopt, for it avoids the necessity for separate purification works at every mill in a district, with the multiplied chances of neglect or mismanagement, and substitutes one set of purification works under constant and more or less skilled supervision. It will also be obvious that such a course will be more economical. So long ago as 1872, indeed, the Rivers Pollution Commission, 1868, in their Fourth Report, p. 105, recommended this course, for they say that

> "any law having for its object the prevention of river pollution should give power to all manufacturers in towns, except those of gas, paraffin oil, pyroligneous acid, and animal charcoal, and workers in metal, to discharge their drainage waters into the town sewers under suitable regulations."

In the past, for various reasons, many manufacturers have been able, with or without the knowledge and consent of the Sanitary Authority, to connect up their mill drains with the public sewers. Very often this has resulted from the fact that the mill premises were originally drained into a small water-course or surface water drain, which was afterwards converted to a common sewer and connected up to sewage disposal works. Formerly, when the sewage of towns was generally discharged into streams without any attempt being made to purify it, it was a matter of little moment to a Sanitary Authority whether or not they received trade refuse into the sewers, and many existing connections date from this period. Sometimes a Sanitary Authority have allowed a manufacturer to connect up his drains because they find him a profitable customer for their water supply or a large ratepayer, and in other cases the same policy has been followed, because the manufacturers are the most influential men in the district. As a result, about half of the manufacturers in the country have obtained this privilege, and in effect are relieved of the responsibility of purifying their refuse. The other half, who discharge their refuse to streams, are not only responsible for its effective purification, but often have to contribute through the rates towards the purification of the refuse of their more lucky neighbours, who may be competitors in the same trade.

The general ratepayer views the matter from a different standpoint. The admission of trade refuse to the sewers of a town almost always renders the sewage more difficult to purify (see p. 309), may bring about serious injury to the sewers by the action of the trade refuse, and at least involves the construction of larger sewage works to deal with the larger volume. The ordinary householder naturally objects to this increased burden on the rates, due to what he considers should legitimately be a charge upon the trader; while the trader in another line of business, who has no liquid refuse to get rid of, objects perhaps more strongly, inasmuch as he himself nearly always has to pay for the removal and disposal of any solid refuse he may produce.

The present condition of affairs has thus given rise to great dissatisfaction, and the whole matter was in 1898 referred to the Royal Commission on Sewage Disposal, who in their Third Report, issued in 1903, made most important recommendations, which will be dealt with later. Until the President of the Local Government Board sees fit to introduce fresh legislation based on these recommendations, the matter is governed by the existing law, which is contained in the following Acts of Parliament:—

THE PUBLIC HEALTH ACT, 1875.

SECTION 15.—Every Local Authority . . . shall cause to be made such sewers as may be necessary for effectually draining their district for the purposes of this Act.

SECTION 21.—The owner or occupier of any premises within the district of the local authority shall be entitled to cause his drains to empty into the sewers of that authority. . . .

THE RIVERS POLLUTION PREVENTION ACT, 1876.

SECTION 7.—Every sanitary or other local authority having sewers under their control shall give facilities for enabling manufacturers within their district to carry the liquids proceeding from their factories or manufacturing processes into such sewers:

Provided that this section shall not extend to compel any sanitary or other local authority to admit into their sewers any liquid which would prejudicially affect such sewers or the disposal by sale, application to land, or otherwise, of the sewage matter conveyed along such sewers, or which would from its temperature or otherwise be injurious in a sanitary point of view:

Provided also, that no sanitary authority shall be required to give such

facilities as aforesaid where the sewers of such authority are only sufficient for the requirements of their district, nor where such facilities would interfere with any order of any court of competent jurisdiction respecting the sewage of such authority.

THE PUBLIC HEALTH ACTS (AMENDMENT) ACT, 1890.

(This Act must be adopted by a Sanitary Authority before it becomes operative within their District.)

SECTION 16.—(1) It shall not be lawful for any person to throw, or suffer to be thrown, or to pass into any sewer of a local authority or any drain communicating therewith, any matter or substance by which the free flow of the sewage or surface or storm water may be interfered with, or by which any such sewer or drain may be injured. . . .

SECTION 17.—(1) Every person who turns or permits to enter into any sewer of a local authority or any drain communicating therewith—

(*a*) Any chemical refuse, or

(*b*) Any waste steam, condensing water, heated water, or other liquid (such water or other liquid being of a higher temperature than 110 degrees Fahrenheit),

which, either alone or in combination with the sewage, causes a nuisance or is dangerous or injurious to health, shall be liable to a penalty not exceeding ten pounds, and to a daily penalty not exceeding five pounds.

Although the law as expressed in these Acts is at first sight sufficiently clear, legal difficulties have arisen on many points, and have had to be decided by expensive litigation. For example, it has now been settled that under Section 15 of the Act of 1875 as applied to England, a Local Authority are not obliged to make sewers larger than is necessary to take the domestic sewage of their District. In the case of *Peebles* v. *Oswaldtwistle Urban District Council* (1898, A.C. 387), it was decided by the House of Lords that where the sewers of a District are alleged to be insufficient, the proper remedy is by complaint to the Local Government Board under Section 299 of the Public Health Act, 1875, and when Messrs Mallalieu made a complaint under this section that the Saddleworth Urban District Council had made default in that they had not provided sewers sufficient to take their trade refuse, the English Local Government Board held, after inquiry (21st June 1898), that the Sanitary Authority had not made default, implying that they did not consider it the duty of the Authority to make their sewers large enough to take the trade refuse of their District. This, as will afterwards be shown, is not the view of the Local Government Board for Scotland.

Again, in the case of *Brook* (*Limited*) v. *Meltham Urban District Council* (1908, 2 K.B. 780), it was held by the Court of Appeal that Section 21 of the Public Health Act, 1875, does not give a manufacturer a right to discharge his manufacturing effluent into the sewers of the Local Authority; and this is confirmed by Lord Macnaghten's judgment in the case of the *West Riding of Yorkshire Rivers Board* v. *Butterworth and Roberts* (1909, A.C., at p. 54).

Section 7 of the Rivers Pollution Prevention Act, 1876, seems at first sight to be sufficiently clear and definite, but, while the first part of the Section insists upon the duty of the Sanitary Authority to take the liquid trade refuse into the public sewers, the provisoes added there and the two

Sections of the Public Health Acts (Amendment) Act, 1890, give ample scope for legal disputation.

There are perhaps few kinds of trade refuse which, if mixed in a crude state with ordinary domestic sewage, would not affect prejudicially the disposal of sewage, and there are many kinds of trade refuse which could be shown to affect the sewers prejudicially, or to be injurious from a sanitary point of view. Moreover, a Sanitary Authority can often easily show that their sewers are only sufficient for the reception of the domestic sewage of their District, or that their sewage works are not large enough to deal with trade refuse, and it has been held in the case of *Brook (Limited)* v. *Meltham Urban District Council* (1909, A.C. 438) that the word "sewers" in the proviso covers the whole sewerage system, including purification works.

In a District in which a new sewage scheme is being carried out, it is easy for the Sanitary Authority to make their works only large enough to deal with domestic sewage. It is indeed the view of the English Local Government Board that such works need not be large enough to take trade refuse. On the other hand, the Local Government Board for Scotland (Murray, Royal Commission on Sewage Disposal, 1898, First Report, vol. ii. p. 16, Q. 191), advised by their law officers, have come to the conclusion that a Sanitary Authority in making new sewers must provide them large enough for all the sewage of their District, including trade refuse as well as domestic sewage; but the Scotch law on the matter is somewhat different, being governed by the Public Health (Scotland) Act, 1897, afterwards quoted. Many Sanitary Authorities have made their sewers big enough for both kinds of liquids, while their sewage disposal works are only sufficient for dealing with domestic sewage, so that if it is decided in the future that they must deal with trade refuse, the sewers will not require to be relaid, and an extension of the sewage works will meet their increased needs.

Before the above-mentioned cases were decided, several Sanitary Authorities obtained special Acts dealing with the matter. These are:—

GLASGOW POLICE ACT, 1866.
WOLVERHAMPTON IMPROVEMENT ACT, 1869.
HUDDERSFIELD IMPROVEMENT ACT, 1871.
NOTTINGHAM AND LEEN DISTRICT SEWERAGE ACT, 1872.
NOTTINGHAM IMPROVEMENT ACT, 1874.
DEWSBURY IMPROVEMENT ACT, 1884.
BURY IMPROVEMENT ACT, 1885.
HASTINGS IMPROVEMENT ACT, 1885.
WALSALL CORPORATION ACT, 1890.
WOLVERHAMPTON CORPORATION ACT, 1891.
THE WEST RIDING OF YORKSHIRE RIVERS ACT, 1894.
BILSTON IMPROVEMENT ACT, 1896.
BRADFORD TRAMWAYS AND IMPROVEMENT ACT, 1897.
KEIGHLEY CORPORATION WATERWORKS ACT, 1898.
GLASGOW CORPORATION (SEWAGE, ETC.) ACT, 1898.
MANCHESTER CORPORATION (GENERAL POWERS) ACT, 1902.

The Alkali Works Regulation Act, 1906, following the Act of 1881, which has been repealed, has a Section bearing on this question, and two Scotch Acts also deal with it.

ALKALI WORKS REGULATION ACT, 1906.

SECTION 3.—(1) Every work of whatever description in which any liquid containing either acid or any other substance capable of liberating sulphuretted hydrogen from alkali waste or drainage therefrom is produced or used shall be carried on in such manner that the liquid shall not come in contact with alkali waste, or with drainage therefrom, so as to cause a nuisance.

(2) The owner of any work which is carried on in contravention of this section shall be liable to a fine not exceeding in the case of the first offence fifty pounds, and in the case of every subsequent offence one hundred pounds, with a further sum not exceeding five pounds for every day during which any such subsequent offence has continued.

(3) On the request of the owner of any such work as is mentioned in this section the sanitary authority of the district in which such work is situate shall, at the expense of such owner, provide and maintain a drain or channel for carrying off such liquid as aforesaid produced in such work into the sea or into any river or watercourse into which the liquid can be carried without contravention of the Rivers Pollution Prevention Act, 1876, as amended by any subsequent enactment; and the sanitary authority shall for the purpose of providing any such drain or channel have the like powers as they have for providing sewers, whether within or without their district, under the Public Health Act.

(4) Compensation shall be made to any person for any damage sustained by him by reason of the exercise by a sanitary authority of the powers conferred by this section, and such compensation shall be deemed part of the expenses to be paid by the owner making the request to the sanitary authority under this section.

SECTION 4.—(1) Alkali waste shall not be deposited or discharged without the best practicable means being used for effectually preventing any nuisance arising therefrom.

(2) Any person who causes or knowingly permits any alkali waste to be deposited or discharged in contravention of this section shall be liable to a fine not exceeding in the case of the first offence twenty pounds, and in the case of every subsequent offence fifty pounds, with a further sum not exceeding five pounds for every day during which any such subsequent offence has continued.

SECTION 5.—Where alkali waste has been deposited or discharged, either before or after the commencement of this Act, and complaint is made to the chief inspector that a nuisance is occasioned thereby, the chief inspector, if satisfied of the existence of the nuisance, and that it is within the power of the owner or occupier of the land to abate it, shall serve a notice on such owner or occupier requiring him to abate the nuisance; and if such owner or occupier fails to use the best practicable and reasonably available means for the abatement thereof, he shall be liable to a fine not exceeding twenty pounds, and, if he does not proceed to use such means within such time as may be limited by the court inflicting such fine, he shall be liable to a further penalty not exceeding five pounds for every day after the expiration of the time so limited during which such failure continues.

THE BURGH POLICE (SCOTLAND) ACT, 1892.

SECTION 233.—Any owner or occupier of distilleries, manufactories, or other works, who causes or permits any refuse, refuse water, steam, or other substances fitted to interrupt the free passage of a sewer, or to be otherwise injurious thereto, or to be injurious to the health of persons living in the vicinity, to enter a public sewer, river, or inland loch, or public reservoir, or dock, from any such works, shall be guilty of an offence, and shall, on conviction before the Sheriff, be liable to a penalty of five pounds for every day or part of a day during which such offence continues, besides being liable for all damages, and for all expenses for taking out of the sewer any refuse or substance that may have entered it from his works.

Such owners or occupiers shall construct pools or reservoirs as near their works as possible for receiving and depositing such refuse and other substances.

If it shall be impracticable, in the judgment of the Commissioners, to render such refuse or other substances inoffensive or innocuous, or to prevent the same from interrupting the free passage of the sewer, or otherwise injuring the same, it shall be lawful for the Commissioners to prohibit and interdict such owner or occupier from permitting the same to run into such sewer from his works aforesaid; and while such prohibition and interdict are in force, or if, and so long as the owner or occupier of such works makes no use of the sewers, in consequence of having, before this Act came into operation, made separate arrangements for the drainage of the works, such owner or occupier shall be entitled to be exempted from the sewer rates to the extent of seventy-five per centum thereof, applicable to the whole building or such part or parts thereof as by such prohibition or previous separate arrangement are deprived directly or indirectly of any benefit from the sewer; provided that the sewer rates payable in respect of the other parts of such distilleries, manufactories, and other works, and all warehouses, offices, and other buildings connected therewith, shall still remain payable; and if the prohibition and interdict be at any time, by the Commissioners, withdrawn, or the owner or occupier having previous separate arrangements shall begin to use the sewers, then the exemption shall cease so soon as the owner or occupier avails himself, to any extent, of the withdrawal of the prohibition by permitting the substances prohibited to pass into the sewers, and if the owner or occupier is dissatisfied with the decision of the Commissioners as to the practicability aforesaid, or as to the part of the works for which such exemption ought to be made, it shall be lawful for such owner or occupier to appeal to the Sheriff in manner after provided.

THE PUBLIC HEALTH (SCOTLAND) ACT, 1897.

SECTION 110.—Any owner or occupier of premises within the district of a local authority liable for the public health general assessment or special sewer assessment shall be entitled to cause his drains to empty into the sewers of such local authority on condition of his giving twenty days' previous notice of his intention so to do to the local authority, and of complying with their regulations in respect of the mode in which the communications between such drains and sewers are to be made, and subject to the control of any person who may be appointed by the local authority to superintend the making of such communications. Provided always that the sewage so emptied or discharged into the sewers is not of a nature to cause damage to the structure of the sewer or, by admixture with other sewage therein, to cause a nuisance.

SECTION 116.—The owners or occupiers of distilleries, manufactories, and other works shall be compelled, where possible, to dig, make, and construct pools or reservoirs within their own ground, or as near their works as possible, for receiving and depositing the refuse of such works so far as offensive or injurious or dangerous to the health of those living in the vicinity thereof, or to use the best practicable means for rendering the same inoffensive or innoxious before discharging it into any river, stream, ditch, sewer, or other channel.

SECTION 117.—(1) It shall not be lawful for any person to throw or suffer to be thrown or to pass into any sewer of a local authority, or any drain communicating therewith, any matter or substance by which the free flow of the sewage or surface or storm water may be interfered with, or by which any such sewer or drain may be injured.

(2) Every person offending against this enactment shall be liable to a penalty not exceeding ten pounds, and to a daily penalty not exceeding twenty shillings.

SECTION 120.—If a house, distillery, manufactory, or other work, within the district of a local authority, is without a drain, or without such drain as is sufficient for effectual drainage, the local authority may, by notice, require the owner of such house, distillery, manufactory, or work, within a reasonable time therein specified, to make a sufficient drain emptying into any sewer which the local authority are entitled to use, and with which the owner is entitled to make a communication, so that such sewer be not more than one hundred yards from the site of the said premises of such owner; but if no such means of drainage are within that distance, then emptying into such covered cesspool or other place, not being under any house, as the local authority may direct; and if the person on whom such notice is served fails to comply with the same, the local authority may, at the expiration of the time specified in the notice, do the work required, and the expenses incurred by them in so doing may be recovered from such owner in a summary manner.

Provided that where in the opinion of the local authority greater expenses would be incurred in causing the drains of two or more houses to empty into an existing sewer pursuant to this section than in constructing a new sewer and causing such drains to empty therein, the local authority may construct such sewer and require the owners of such houses to cause their drains to empty therein, and may apportion as they deem just the expenses of construction of such sewer among the owners of the several houses, and recover in a summary manner the sums apportioned from such owners, or in case of dispute the matter shall be determined summarily by the sheriff.

There are few additional points in these Acts. The Glasgow Act of 1866 gives the Corporation power to compel the construction of special trade sewers in certain cases. The Wolverhampton, Huddersfield, Nottingham, Bilston, Bradford, and Keighley Acts safeguard the manufacturer who may be turning objectionable refuse into the sewers, provided that he has used the best practicable means for previously removing the objectionable matters. The Bradford Act provides for the compensation of certain manufacturers before the Act can be enforced against them, and, like the Bury Act, defines that dyers are to provide settling pools for their waste waters before discharging these into a public sewer. The Glasgow Act of 1898 prohibits the discharge into the sewers of any liquid which would be injurious to the construction or efficiency of the sewers or sewage works. The Alkali Act of 1906 allows a Sanitary Authority to construct a private drain for certain kinds of trade refuse in the same manner and under the same powers as a public sewer; and the Burgh Police (Scotland) Act, 1892, like the Bradford Act, defines to some extent the purification works to be constructed by the manufacturers or the owners of manufactories, and in addition provides for the reduction of the sewer rate payable by any manufacturer who has provided separate arrangements for the drainage of his works. The West Riding of Yorkshire Rivers Act, 1894, only repeats the provisions of Section 7 of the general Act of 1876. In the Manchester Act, 1902, nothing is said with regard to trade refuse interfering with the treatment of the sewage, but the Corporation are given the power to prohibit the discharge into the sewer of matters which may be injurious to the sewers, or may cause a nuisance or involve danger to the health of persons entering the sewers or others. If any person disputes the reasonableness of any such prohibition he may appeal to a referee appointed by the Stipendiary Magistrate. The Act also gives the Corporation power to construct an inspection chamber on the drain within any manufacturing premises connected with the sewers.

The Public Health (Scotland) Act, 1897, deserves special notice. It apparently takes as undoubted the duty of a Sanitary Authority to receive all manufacturing refuse in their District into the sewers and the right of a manufacturer thus to discharge his refuse, provided that it will not damage the sewers or cause a nuisance, and enacts by Section 116 that the owners or occupiers of manufactories are to be compelled to provide settling tanks for the removal of offensive and injurious substances from their refuse before discharging it from their premises. It must also be noted that nothing is said in this Section of the effect of the trade refuse on the treatment of the combined sewage, it may be because this side of the question is already dealt with sufficiently in the general Rivers Pollution Prevention Act, 1876.

The Third Report of the Royal Commission, 1898, issued in 1903, marks a distinct stage in the development of the question. The Commissioners state:

> Par. (22) We are therefore of opinion that the law should be altered so as to make it the duty of the Local Authority to provide such sewers as are necessary to carry trade effluents as well as domestic sewage, and that the manufacturer should be given the right, subject to the observance of certain safeguards, to discharge trade effluents into the sewers of the Local Authority if he wishes to do so. . . . In each district it would probably be desirable that the Local Authority should frame regulations which should be subject to confirmation by a Central Authority. . . .
>
> (23) Although the duty of receiving trade effluents should, we think, be imposed on the Local Authority, cases may arise in which they should be wholly or partially relieved of it. . . . And it is possible that in some cases as, for example, of a large manufactory being newly established in a small District, it might be necessary to relieve the Authority of the obligation to treat the trade effluent or to enable them to exact some special contribution from the manufacturer not only for the cost of treatment but also towards capital expenditure.
>
> (24) It is obvious, therefore, that some tribunal will be required for settling differences between the Local Authority and the manufacturer, and for relieving the Local Authority in exceptional cases either wholly or partially of their obligation to provide sewers and disposal works of sufficient capacity for trade effluents as well as ordinary sewage . . .
>
> (25) In many cases a part or the whole of the water which the manufacturer uses in his business is obtained from a stream and must therefore be returned to the stream. We do not propose that the manufacturer should by statute be relieved of this liability. If he is able to relieve himself from the obligation by obtaining the necessary consents from other riparian owners or by providing compensation water, then he might discharge his effluent into the sewer, but the responsibility must rest entirely on the manufacturer: the Local Authority should be expressly exempted from any liability for the infringement of riparian rights by the discharge into the sewer of water obtained from a stream.
>
> (29) Having regard to these considerations, we are of opinion that generally no special charge should be made on the manufacturer in those cases in which the regulations as to preliminary treatment are complied with. As we have already stated, it is desirable that wherever practicable, some preliminary treatment should be carried out by the manufacturer. But where the manufacturer is unable to comply with these regulations we consider that the Local Authority should be empowered to make a special charge. Power should also be granted to make a special charge, even when preliminary treatment is adopted, where there are exceptional circumstances as regards volume, quality, or otherwise.
>
> (30) We should leave the actual amount of the charges to be fixed by agree-

ment between the manufacturer and the Local Authority. In default of agreement the amount should be settled by a superior authority. . . .

(34) . . . We consider that all manufacturers should be placed on the same footing, and that the proposals which we have made as to preliminary treatment by the manufacturer and as to a special charge being made upon him by the Local Authority in certain cases, should apply equally to the manufacturer whose trade effluent already passes into the sewer and to the manufacturer who is only proposing to obtain a connection.

(38) It may also sometimes be necessary for the Local Authority to construct a sewer for the reception of trade refuse alone, and, in certain circumstances, it may be desirable that the Local Authority should provide a separate system of trade sewers, and also works for the partial treatment of trade effluents before they are mixed with the ordinary sewage for final purification. If powers to construct such works are not already possessed by Local Authorities, they should be conferred upon them.

(39) . . . We think it desirable that power to undertake the disposal of sludge at the expense of the manufacturer should be conferred on the Local Authority. We do not think, however, that the manufacturer should be empowered to compel such removal. If compulsion is necessary, this should be exercised by a superior authority in the manner hereinafter explained.

(44) . . . We unhesitatingly recommend the creation of such an Authority . . . for the determination of differences between the Local Authority and the manufacturer. . . .

(56) In our opinion it is desirable that such differences should be settled by the Rivers Boards whenever this can be done, and, having regard to the valuable experience which these bodies have accumulated, to the fact that they represent large areas and possess capable officers, and to the confidence which they command, we think the following cases might very properly be referred to them in the first instance, power being given to either party to appeal to the Central Authority :—

1. Differences between the manufacturer and the Local Authority as to variation of the general regulations respecting preliminary treatment to meet particular cases.
2. Differences as to the amount of the special charge to be imposed on the particular manufacturer.
3. Disputes as to whether the preliminary treatment adopted by the particular manufacturer complies with the regulations.
4. Differences as to the removal of sludge.

(57) We think, however, at any rate for the present, that the following cases should be dealt with by the Central Authority alone :—

(*a*) Refusal of a Local Authority to allow a particular trade effluent to enter their sewers.

(*b*) Refusal of a Local Authority to construct or enlarge sewers for the purpose of a particular manufactory. . . .

(61) . . . We do not, however, consider that the Central Authority should take the place of local bodies in regard to the protection of rivers and other sources of water supply. On the contrary, we think local power should be utilised to the fullest extent possible. . . .

(62) In our opinion such power can only be fully utilised by the formation of Rivers Boards throughout the country, and we therefore recommend that such Boards should be formed.

(70) The Central Authority should exercise a general superintendence over the whole country in regard to the prevention of pollution of water. They should direct any inquiries or investigations which they may consider desirable, and generally they should stimulate and encourage Rivers Boards to an active exercise of their powers.

Although no general Act of Parliament dealing with the subject has been passed since these recommendations were issued, there have been three local Acts based on them which have been passed by agreement between the Local Authorities and the manufacturers, and these put all the manufacturers upon the same footing, whether their premises previously drained to the sewers or no. These are:—

HALIFAX CORPORATION ACT, 1905, PART II.
HECKMONDWIKE IMPROVEMENT ACT, 1905, PART VIII.
HUDDERSFIELD CORPORATION ACT, 1906, PART II.

The three Acts are very similar in their provisions, and it may suffice to describe these in the latest, the Huddersfield Act. A trader is given the right, with certain exceptions, to discharge his trade refuse into the sewer; on the other hand, regulations are to be made providing for the exclusion of clean water, the removal of solids and grease, and the regulation of the flow of refuse, so as to ensure a uniform rate of discharge into the sewers during each working day. The regulations are to provide for payment by the trader where he is unable to remove the solids and grease, or to regulate the flow, or in other exceptional cases, and these regulations are to be settled by agreement between the Corporation and representatives of the traders. If any dispute arises it may be referred to the Local Government Board or to arbitration under the Arbitration Act, 1889. The Corporation are given the same powers and duties with regard to the removal and disposal of trade refuse as they have with regard to sewage under the Public Health Act, 1875. They may also, at the cost of any trader, remove and dispose of any sludge produced in the treatment of trade refuse upon trade premises.

Apart from all special Acts of Parliament, local or general, dealing with the matter, the common law of riparian rights has a great bearing on it. A riparian owner has the right to all the water flowing, or which would flow, naturally, down a stream, and it may therefore be impossible for a manufacturer who uses water drawn from a stream to turn it, when polluted, into the public sewer, and thus to let it be conveyed away from the premises of an owner of property lower down. Very frequently, however, in such cases the manufacturer has other sources of water supply, say from a well or the town's mains, and can return to the stream a quantity of water from his less polluting processes equal to that drawn from the stream, while the more polluting part of his trade refuse is turned into the public sewer; or it may even pay a manufacturer to sink a well or get his water from the public supply so as to be able to divert his liquid refuse from a stream, rather than to construct the special purification works necessary to enable him to continue discharging into the stream.

In one way or another most Sanitary Authorities who have control of Districts in which there are important manufacturing interests to consider have admitted trade refuse into the public sewers, and, having done so, it seems doubtful if they have power to revoke their decision and to cut off any manufacturer who has been permitted to connect up his drains to the sewers. What power they may have under the provisoes of Section 7 of the Act of 1876 is very difficult to enforce, and may apparently be set at naught by a manufacturer who adopts measures to remove from his trade refuse anything that would interfere with the treatment of the sewage with which his refuse is mixed [see *Eastwood Brothers* (*Limited*) v. *Honley Urban District Council* (1900, 1 Ch. 781, and 1901, 1 Ch., 645); also *Attorney General and Sevenoaks Rural District Council* v. *Whitmore*, "The Times," 25th July 1900; and *Southall Norwood Urban District Council* v. *Middlesex County Council* (1901, 83 L.T. (N.S.) 742)].

When a Sanitary Authority are requested by a manufacturer to deal with his trade refuse they have to consider upon what conditions they will permit him to connect his drains to the sewers, for, as has been stated, this connection is certain to involve an increased cost for sewage disposal, and some kinds of refuse are likely to cause injury to the sewers. Cases are on record, for instance, where the discharge of sulphate of lime has blocked the sewers, acid refuse has destroyed them by corrosion, and carbon bisulphide or petrol has given rise to explosions. The Sanitary Authority should therefore have power to make regulations governing the admission of refuse, and these in the case of new connections can generally be arranged by formal agreements.

In most cases a preliminary partial purification of the trade refuse is now demanded, or, failing this, a payment by the trader towards the increased cost of sewage treatment due to the presence of his trade refuse. This is only reasonable in view of the greatly increased cost of dealing with a sewage containing any large proportion of crude trade refuse, and the various troubles and difficulties which the refuse may cause in the sewers and at the sewage works. For example, waste dyewaters often contain large amounts of suspended solids and are often strongly acid in reaction, the solids increasing the sludge difficulty which is always present at sewage works, and the acidity requiring the addition of enormous quantities of lime for its neutralisation; tannery and brewery refuse are strongly charged with suspended solids, and, moreover, contain in solution elements which interfere seriously with the process of sewage purification; the suds from wool washing, piece scouring, and silk boiling in their crude state render a sewage much more difficult and expensive to purify because they contain large amounts of fatty matter, which coagulates in settling tanks and produces a thin and watery sludge, chokes up filters, and coats irrigation areas with an almost waterproof covering; liquids such as waste pickle from wire works and spent gas liquor may interfere disastrously with the living organisms upon which sewage purification in all cases finally depends.

A comparison of the composition of ordinary domestic sewage with some of the forms of crude trade refuse shows at once the more polluting character of the latter, and the object of any preliminary treatment demanded may be taken to be the purification of the trade refuse only so far as to make it no stronger in polluting character than ordinary sewage, and to free it from everything which would unduly interfere with the effective purification of the combined sewage (see Tables LXXIV. and LXXV.).

TABLE LXXIV.

CRUDE TRADE REFUSE,—AVERAGES OF SEVERAL ANALYSES.

(Results expressed in parts per 100,000.)

Nature of Liquid.	Total Solids.	Solids in Suspension (dried at 100° C.).		Solids in Solution (dried at 100° C.).		Nitrogen.		Oxygen absorbed from $\frac{N}{80}$ permanganate in four hours at 26·7° C.	Hardness (in terms of $CaCO_3$).			Total Fatty Matter.	Alkalinity (as $CaCO_3$).	Acid required to crack (as H_2SO_4).
		Total.	Ash.	Total.	Ash.	Ammoniacal.	Organic (Kjeldahl).		Total.	Permt	Temp.			
Tanners' refuse	737·2	218·5	102·4	518·7	367·5	9·57	13·38	86·2	211·7	140·2	71·5	...	164·0	..
Fellmongers' refuse	634·0	297·2	196·5	336·8	245·0	7·38	17·12	26·0	49·5	27·2	22·3	...	12·5	...
Wool-washing refuse	2239·2	1628·0	392·8	611·2	276·9	11·50	22·61	88·7	115·7	0·0	115·7	1237·8	..	162·5
Piece-scouring refuse	640·2	315·8	37·3	324·4	214·0	1·51	10·57	53·2	5·3	0·0	5·3	224·4	..	122·5
Blanket-scouring refuse	1604·0	1144·5	778·5	459·5	347·5	3·57	13·45	76·5	...	..	...	...	..	.
Spent gas liquor	714·9	51·2	40·4	663·7	328·8	90·59	17·75	238·1	...	.		...	112·6	
Dyewater	464·3	244·3	37·0	220·0	170·9	0·30	3·55	99·4	130·7	81·7	49·0	..	.	...
Spent pickle *	...	109·6	...	...	...	...	.	683·3	...	...	...	...	..	..
Silk-scouring refuse	1024·1	304·9	36·7	719·2	110·1	18·94	87·00	107·9	...	...	...	155·3	...	149·9
Brewers' refuse	205·2	85·3	9·4	119·9	54·2	2·46	12·31	25·5	72·1	52·5	19·6	...	...	..
Papermakers' refuse	122·9	56·2	31·5	66·7	50·1	0·00	0·78	4·9	17·9	8·0	9·9	...	..	..
Coal-washing refuse	6062·1	5709·0	1261·7	353·1	322·1	...	...	.	...	.	...	.	..	...

* Acidity (as H_2SO_4) 4360. Total iron (as Fe) 6679.

The preliminary treatment of trade refuse is secured by various Sanitary Authorities in different ways. Bingley, Bradford, and Manchester call upon the manufacturer to sign an agreement. Many Authorities, as, for instance, Brighouse, Keighley, Leeds, Liversedge, and Manchester, have drawn up certain conditions which must be fulfilled by the manufacturer. Sometimes the Surveyors prepare a typical set of plans for the information of the manufacturers, which need not be followed closely, but which can be adapted to the circumstances of any individual case: this course has been adopted at Brighouse, Elland, and Ossett. Some Authorities require the manufacturer to prepare plans of purification works and to submit them for their approval: this, for example, is the course taken in

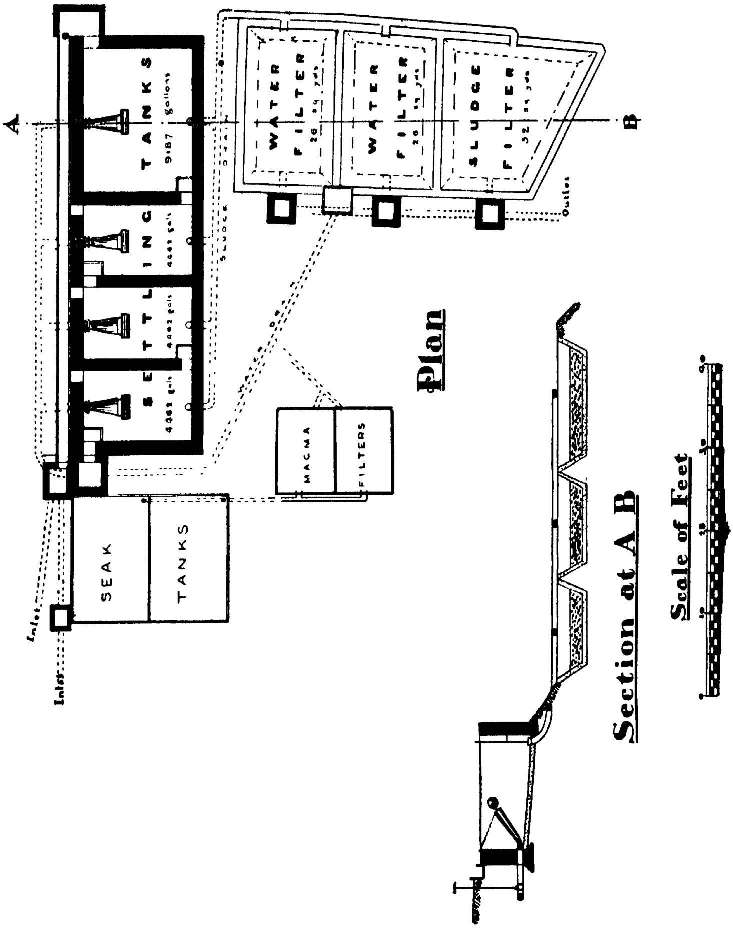

FIG. 67.—Works for the preliminary treatment of Refuse from a Woollen Mill.

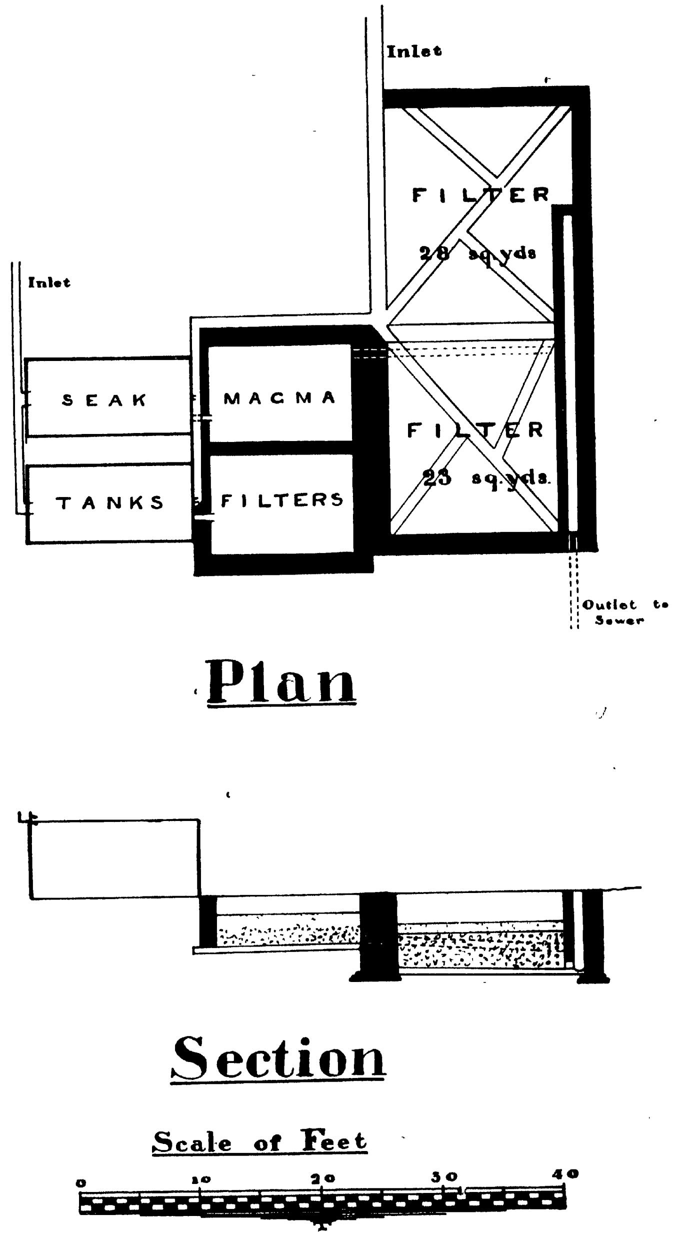

FIG. 68.—Works for the preliminary treatment of Refuse from a Woollen Mill.

Bristol, Leeds, Leicester, and Pudsey. In a few cases the Authorities, doubtful of committing themselves by approving of the plans of any purification works, simply inform the manufacturer that he may connect his drain to the public sewer, but that he must remove from his trade refuse anything which will interfere with the treatment of the sewage: this is the course which has been adopted in the past at Morley and Wakefield. At Salford and Hyde the Corporation undertake to remove and dispose of any sludge collected in preliminary treatment works free of any charge to the manufacturer. And finally, in more than one instance the Authority has made an agreement with the manufacturers in the district to allow trade refuse to be discharged into the sewers on condition that the manufacturers will subscribe towards the increased cost of the sewage works necessary, or the increased working expenses of sewage treatment, or both: this, for example, is the bargain entered into at Tadcaster, Mossley, and New Mill.

Figs. 67 and 68 show plans and sections of works which have been provided at two mills for the preliminary treatment of trade refuse. At these mills the trade refuse is from wool washing, piece scouring, and dyeing, and the total volume of liquid refuse is some 15,000 gallons per day in each case.

For the conditions imposed upon the manufacturers the regulations made by the Corporation of Manchester may be taken as an example.

MANCHESTER CORPORATION.

Regulations for Admission of Trade Refuse into Sewers.

1. All liquid trade refuse from the manufactory shall be passed into and through suitable settling tanks to be approved by the Corporation, the same to be constructed and at all times maintained by and at the cost of the Owner to the satisfaction of the Corporation.

2. By means of the settling tanks and by such other means as shall be from time to time approved by the Corporation the resulting effluent shall be made:—

(*a*) free from solids in suspension beyond 15 grains to the gallon;

(*b*) free from any substance, matter, or thing which shall or may (either alone or in combination with other matter or liquid, or with the ordinary sewage)

(i.) be injurious to the structure or materials of the sewers or works of the Corporation

(ii.) be injurious to the sewers or the sewage therein,

(iii.) cause or create a nuisance either within or without the sewers, and

(iv.) be dangerous or injurious to health either within or without the sewers;

(*c*) free from any substance, matter, or thing the discharge of which into the sewers may contravene any public or local Act of Parliament or Rule of Law.

3. The Owner shall remove as frequently as may be necessary from the settling tanks all solid refuse and solid matter which may be from time to time deposited therein.

4. Only the effluent from the settling tanks which complies with Regulation 2 shall be discharged into the sewers.

5. The maximum aggregate daily quantity of effluent which may pass from the manufactory into the sewer shall be agreed between the Owner

and the Corporation before any connection with the sewer is made or any works for that purpose are commenced. The size and capacity of the drain for conveying the effluent from the manufactory to the sewer shall be determined by the City Surveyor, and shall be such as, having regard as well to the agreed maximum aggregate daily quantity of effluent as to the intended inclination of the drain, will be necessary to secure that only such agreed quantity shall and may be conveyed into the sewer at a uniform and regular rate of flow throughout the twenty-four hours of every day.

6. The Owner shall provide and efficiently maintain a reservoir or receptacle at the manufactory sufficient to hold at least one half the agreed maximum aggregate daily quantity of effluent and shall cause the effluent to pass into such reservoir or receptacle and be thence conveyed by the drain into the sewer.

7. There shall be constructed and maintained by and at the cost of the Owner at or near the outlet of the drain into the sewer an examination shaft and apparatus so designed as to enable the Corporation or their officers to obtain at pleasure from time to time samples of the effluent discharged into the sewer.

8. The works shall be constructed and carried out to the satisfaction in all respects of the City Surveyor and shall be at all times subject to these Regulations and the Acts of Parliament (public or local), Bye-laws and Regulations for the time being in force in the City of Manchester in relation to the subject matter of these Regulations. In particular, in the works of excavating for and making and maintaining the drain or anything therein or connected therewith the Owner will adopt such measures and generally carry out the works in such manner as shall be suggested or required by the City Surveyor for ensuring the satisfactory execution of the work for effectually protecting the sewers, drains, gas and water pipes, wires, tramlines, and apparatus for ensuring perfect stability for the surface of the street and for preventing the complete stoppage of the traffic thereon, Provided that the fact of the City Surveyor giving or failing to give any instructions or directions respecting the works shall not relieve or exonerate the Owner from any obligations or liability imposed upon him by these regulations or at law.

9. Any work of removing the pavement and flagging of the street and of restoring and making good the same shall be done by the Corporation at the expense of the Owner, and the Owner shall pay any such expense to the Corporation on demand.

10. The Owner shall permit the City Surveyor or any other duly authorised officer of the Corporation to enter the manufactory from time to time and to inspect the condition thereof.

11. If at any time the works provided for by these regulations or any of them or anything therein respectively shall in the opinion of the Corporation or the City Surveyor be in a dilapidated, unsafe, inefficient, or unsatisfactory condition, or if the same shall not be kept and maintained in proper working order or shall not be duly and properly fulfilling these regulations in all respects, or if proper arrangements for removing the solids from the trade refuse are not in regular and constant operation, it shall be lawful for, but not obligatory on, the Corporation, in addition and without prejudice to their other remedies, by statute or contract, at the risk and cost of the Owner (after first giving to the Owner one week's notice in this behalf), either to repair, reinstate, or complete the same, or to remove and disconnect the drain from the sewer, as the Corporation in their absolute discretion may think fit, and to enter upon the property of the Owner for the purpose of executing the necessary works in that behalf. The Owner shall pay to the Corporation on demand the cost to be incurred by the Corporation in any such work of repair, reinstatement, completion, or disconnection, such cost to be from time to time ascertained and certified by the City Surveyor, whose decision shall be final and binding on all parties.

12. Any cost and expenses which may be incurred by the Corporation, and which under these regulations shall be repayable to them by the Owner, shall include five pounds per centum for superintendence, and shall carry

interest at four pounds per centum per annum from and after the expiration of one calendar month after service upon the Owner of a demand for payment of such costs and expenses.

13. The arrangements contemplated by these regulations do not extend to the reception into the sewers of surface and storm water or of water which has been taken or diverted from a river, stream, or canal.

14. The Owner shall enter into an agreement, to be prepared by the Town Clerk, for securing the due observance of these regulations.

15. In these regulations the following words have the meanings here assigned to them:—

"Owner" means and includes the owner and occupier for the time being of the manufactory,

"Manufactory" includes any works, manufactory, or premises in the City of Manchester in which liquid trade refuse is produced,

"City Surveyor" means the City Surveyor for the time being of the City of Manchester,

and words in the singular number include the plural, and words in the masculine gender include the feminine.

Form of Application.

TO THE CORPORATION OF THE CITY OF MANCHESTER.

I apply for your permission to make a connection from my Works situate . . . .with the Sewer in ....Street, in the City of Manchester, for the purpose of carrying the liquids from such Works into such Sewer.

The trade or process carried on at such Works is that of a......... ... ...

The maximum daily volume of liquids issuing from such Works is about ....gallons.

In the event of my application being complied with, I undertake that the foregoing Regulations shall at all times be duly observed by the Owner and Occupier for the time being of the said Works.

The Owner and Occupier of the Works are prepared to enter into an Agreement for that purpose, to be prepared by the Town Clerk of Manchester.

The Names and Addresses of such Owner and Occupier are :—

Owner... ....
Occupier ....
Signature.. ....
Address.... ....
Date...... . .. .

As an example of the form of agreement entered into, that adopted by the Bradford Corporation may be cited. This deals with cases of new connection to the sewer, and a somewhat different form is used in cases of existing connection.

BRADFORD CORPORATION.

Agreement between Corporation and Manufacturers.

Articles of Agreement made this day of 191 between (hereinafter called "the Firm") of the one part, and the Mayor, Aldermen, and Citizens of the City of Bradford in the County of York (hereinafter called "the Corporation") of the other part, whereas the Firm have made application to the Corporation for permission to connect the premises of the Firm at (hereinafter called "the Premises") with the Sewer of the Corporation in Street in the said City by means of a inch drain between the points A and B on the plan hereto annexed, which drain is intended to convey into the sewers of the Corporation the purified effluent proceeding from the trade processes carried on by the Firm at the Premises, which said purified effluent and drain are hereinafter respectively called "the said effluent," and "the said drain," and whereas the Corporation have agreed to comply with the said application upon and subject to the terms and conditions hereinafter appearing, now these presents witness, and it is hereby mutually agreed by and between the parties hereto as follows, namely:—

(1) The Firm or their Contractor shall not connect the said drain with the said sewer of the Corporation without first obtaining a permit from the City Surveyor for the time being and complying with the regulations in force in the City with respect to the connection of drains with the sewers of the Corporation, nor shall such connection be made until the works hereinafter mentioned for purifying and regulating the flow of the said effluent and for arresting and removing therefrom all solid matters and matters in suspension shall have been completed.

(2) The said drain shall not at any time be used for the purpose of conveying domestic sewage into the sewers of the Corporation. The Firm will not connect any other drain whatsoever with the said drain, nor with the sewers of the Corporation, without first obtaining a permit from the City Surveyor and complying with the regulations with respect to the connection of drains with the sewers of the Corporation which may from time to time be made by the Corporation and be in force in the City.

(3) The Firm will not at any time make use of any drain made or used for the purpose of conveying domestic sewage from the Premises for the purpose of conveying any effluent or refuse of any kind proceeding from the trade processes carried on at the Premises into the sewers of the Corporation, and will so construct and maintain any drain made or used for the purpose of conveying domestic sewage from the Premises, that no effluent or refuse of any kind proceeding from the said trade processes can find its way into such drain.

(4) The Firm shall and will before connecting the said drain with the said sewer of the Corporation provide adequate filters, tanks, and other apparatus sufficient to purify and regulate the flow of the said effluent and to arrest and remove therefrom all solid matters and matters in suspension, and will at all times keep and maintain the said filters, tanks, and other apparatus in good and efficient working order, and will from time to time, if the said filters, tanks, and other apparatus shall in the opinion of the Corporation or their Sewage Works Engineer (hereinafter called "the Engineer") at any time be not in good working order, make and cause to be made such alterations therein and additions thereto as may be necessary to make the said filters, tanks, and other apparatus sufficient to purify and regulate the flow of the said effluent, and to arrest and remove therefrom all solid matters and matters in suspension. The Firm shall and will also from time to time make such amendment or alteration to the satisfaction of the Engineer or of the City Surveyor in respect of the mode of communication between the said drain and the said sewer of the Corporation as the Corporation by writing under the hand of the Engineer or of the City Surveyor shall require.

(5) The Firm will not use or suffer or permit the said drain to be used for any other purpose whatever except for the purpose of carrying the said effluent into the sewers of the Corporation without the express leave in writing of the Corporation under the hand of the Engineer.

(6) The Firm shall and will cause to be passed into and through the said filters, tanks, and other apparatus all the effluent and liquids proceeding from the said trade processes before they are discharged into the said drain.

(7) The Firm shall and will construct and maintain to the satisfaction of the Corporation or the Engineer an inspection chamber on the line of the said drain, in such a position and in such a way that the Engineer

and others, the officers of the Corporation, shall at all times by day and by night have free access to the said drain for the purpose of examining and taking samples of the liquid being discharged from the Premises into the said sewer of the Corporation, and the Firm shall and will at all times of the day and night give and allow to the Engineer and other officers of the Corporation free access to the said chamber.

(8) The Firm shall and will permit the Engineer or any officer of the Corporation duly authorised in this behalf from time to time and at all reasonable times to enter the Premises and to inspect the condition thereof with a view to seeing that the terms and conditions of this Agreement and the provisions herein contained are being duly observed and performed, and that all proper precautions and means for passing all the effluent and liquids proceeding from the said trade processes into and through the said filters, tanks, and other apparatus, and for purifying and regulating the flow of the said effluent and for arresting and removing therefrom all solid matters and matters in suspension are from time to time being taken.

(9) The Firm undertake that the said effluent, when discharged from the Premises into the said sewer of the Corporation, shall be to the satisfaction of the Corporation or the Engineer.

(10) This Agreement is without prejudice to the provisions contained in Part III. of the Public Health Acts (Amendment) Act, 1890, and to the right of the Corporation to take proceedings in the event of any nuisance arising from the premises, and is not to be deemed as in any way authorising a breach of the Injunction of the Court of Chancery now subsisting against the Corporation prohibiting the discharge of sewage not properly purified into the Bradford Beck, or as authorising the admission into the public sewers of any effluent or refuse of any kind from the Premises that would interfere with the treatment or utilisation of the sewage of the City, which is prohibited by the Bradford Tramways and Improvement Act, 1897, and the Rivers Pollution Prevention Act, 1876.

(11) Nothing in this Agreement shall be deemed or held to constitute an admission on the part of the Corporation of any obligation to admit to their sewers or to treat or dispose of trade refuse or effluent.

(12) This Agreement and everything herein contained may be determined at any time by either party giving to the other party three calendar months' written notice of their desire to so determine it, and thereupon the privilege hereby granted to the Firm to pass the said effluent into the sewers shall cease, and at the expiration of the said notice the Firm shall and will disconnect and remove the said drain from the said street after obtaining a permit from the City Surveyor, and complying in all respects with his requirements.

(13) If the Firm shall fail to observe and perform any of the provisions hereinbefore set forth and on their part to be observed or performed, or if the said effluent when discharged into the sewers shall in the opinion of the Corporation or the Engineer prejudicially affect the sewers of the Corporation or the disposal of the sewage matter conveyed along such sewers, or be of a character or have qualities that would make it likely to interfere with the treatment or utilisation of the sewage of the City, or shall be in any other respect not to the satisfaction of the Corporation or the Engineer, it shall be lawful for the Corporation by their servants and agents, after giving to the Firm seven days' notice under the hand of their Town Clerk in that behalf, to absolutely determine this Agreement, and thereupon the privilege hereby granted to the Firm to pass the said effluent into the sewers shall cease, and the Corporation may at any time thereafter disconnect the said drain from the said sewer of the Corporation, and for that purpose enter into and upon the Premises, and dig down to the said drain and block it up without being liable for any loss or damage thereby occasioned to the Firm or to the Premises.

In witness whereof the said
have hereunto set their hands and seals, and the Corporation have caused

their Common Seal to be hereunto affixed the day and year first hereinbefore written.

Signed, sealed, and delivered by the said

The Common Seal of the Corporation was hereunto affixed in the presence of

....

Lord Mayor.

....

Town Clerk.

It should be noted that under the recent Acts of Halifax, Heckmondwike, and Huddersfield, although the Authorities have the power of calling upon the trader to give his refuse a preliminary purification, they have preferred to allow him to discharge it in its crude state into the sewers on condition of his paying according to the nature and volume of his refuse. This is generally the wiser course to adopt, for where preliminary purification is insisted upon it is often found that the works provided by the manufacturer are mismanaged or neglected, and that the effluent discharged into the sewer is nearly as bad as the crude refuse.

The regulations drawn up by agreement between the Corporation of Halifax and the traders are as follows:—

COUNTY BOROUGH OF HALIFAX.

General Regulations pursuant to Section 11 *of the Halifax Corporation Act*, 1905.

MADE BY THE HALIFAX CORPORATION, ON THE 2ND DAY OF OCTOBER 1907.

1. Trade Refuse shall be discharged into a sewer at a uniform and regular rate of flow during working hours, so far as reasonably practicable, and with due regard to space and requirements of the business for the time being carried on on the Trade Premises affected.

2. (*a*) The Corporation may construct and maintain at their cost at or near the outlet of the drain into the Sewer, an examination shaft and apparatus so designed as to enable the Corporation, or their Officers, to obtain from time to time samples of the Trade Refuse discharged into the Sewer.

(*b*) Any sample obtained by the Corporation for the purposes of this Act shall be taken in two bottles of similar size and construction, and shall forthwith, before removal from the premises, be securely sealed up and signed and marked with the date and time of and place where taken by the person taking the same, and one bottle shall be left by such person with the Trader, or his representative for the time being in charge of the Trade Premises affected.

3. Any works shall be constructed and carried out subject to the General Regulations and the Acts of Parliament (public or local) for the time being in force in the Borough of Halifax in relation to the construction of drains and the connection thereof with the Sewers.

4. All Statutory Powers vested in the Corporation for the inspection of drains shall apply to any drain to which this Act applies.

5. (*a*) Any Trader now or hereafter adopting preliminary treatment of Trade Refuse shall provide, maintain, and use on the space to be provided for the purpose all plant and apparatus necessary and proper, so far as reasonably practicable, within the intent and meaning of Section 11, Subsection (3) of the said Act, to effect a preliminary treatment of the Trade Refuse produced by him at the Trade Premises affected, before discharging the same into the sewer, or into any drain communicating therewith.

(*b*) Any Preliminary Treatment Works fulfilling the requirements of Part (*a*) of this Clause, maintained and used at the date when these Regulations shall come into force, shall for all purposes be deemed to have been provided to fulfil the requirements of these Regulations.

(6). (*a*) Wherever the Corporation shall be entitled under the said Act to make any charge for the removal and disposal of Trade Refuse, they may charge the Trader in accordance with the Table set forth in the Schedule hereto.

(*b*) In case of any Industry not coming under one of the several subdivisions of the Classes for the time being mentioned in the said Table being hereafter carried on by any Trader, such Industry shall be entered under one of the said Classes as a sub-division thereof, or shall be entered as an additional class of industry, and a charge fixed thereunder, as may be agreed between the Corporation and the Trader.

(*c*) The quantity of Trade Refuse to which any charge shall apply shall, subject to Clause 7, be agreed between the Corporation and the Trader.

7. If any dispute or difference shall at any time or times hereafter arise between the Corporation and any Trader as to the construction or operation of these Regulations, or in case the parties shall not agree upon any matter which is the subject of Agreement hereunder, either party may refer the same to arbitration in accordance with Section 13 of the above-mentioned Act.

8. In these Regulations, words and expressions to which meanings are assigned in the Public Health Acts, and Rivers Pollution Prevention Act, 1876, and the above-named Act, have the same respective meanings unless there be something in the subject or context repugnant to such constructions.

SCHEDULE.

TABLE OF CHARGES FOR REMOVAL AND DISPOSAL OF TRADE REFUSE.

(Regulation 6)

Class.	Trade.	Charge per Million Gallons. £	s.	d.
1.	Wool combing	10	0	0
	Wool washing			
	Yarn scouring			
	Silk washing			
2.	Curriers	8	0	0
3.	Dripping makers	5	0	0
	Waste bleaching			
	Tripe dressing			
	Chemical works			
4.	Dyeing	3	0	0
	Textile printing			
	Brewing			
	Bottle washing			
	Mineral water works			
	Soap making			
	Gas working			
	Stone sawing			
	Card clothing manufacturing			
	Grain washing			
	Wire works			

The Heckmondwike regulations are identical, and in those of Huddersfield, where most of the manufacturers were discharging their refuse into the sewers before the Act was obtained, a uniform charge of one penny per thousand gallons is made. The Huddersfield regulations may be summarised as follows :—

No. 1 interprets the various terms used.

No. 2 excludes clean waters from the sewers, permitting the trader to discharge them into any existing surface-water sewer.

No. 3 forbids the trader to discharge trade refuse into a surface-water sewer.

No. 4 prescribes tanks and screens; the tanks to be in duplicate and each to be sufficient to contain the maximum flow for six consecutive working hours.

No. 5 excludes all solid matter from the trade refuse and prescribes the use of chemical precipitation where necessary.

No. 6 provides for the removal of grease by chemical treatment.

No. 7 provides for the cleansing of the settling tanks.

No. 8 stipulates that the flow is to be continuous and regular per minute throughout each working day.

No. 9 requires notice from the trader, from time to time, of the volume of trade refuse.

No. 10 provides for a manhole or inspection chamber on the drain, with a lock and key under the control of the Corporation.

No. 11 authorises inspection of any apparatus provided.

No. 12 stipulates that plans of proposed works shall be submitted to the Corporation.

No. 13 requires the trader to pay for the work of connecting to the sewer.

No. 14 entitles the trader, when he cannot comply with the foregoing regulations at a reasonable cost, to discharge his crude refuse into the sewers under payment.

No. 15 provides that the trader who discharges crude trade refuse to the sewers under an agreement with the Corporation, shall pay one penny for every thousand gallons discharged.

No. 16 provides for the settlement of any differences arising, by a committee consisting of four members appointed by the Corporation, and four by the traders, with the mayor of the borough added when the voting is equal.

The effect of the preliminary treatment of trade refuse when it is properly enforced is very marked. For example, one tanner in Leeds, who discharges into the town sewer about 30,000 gallons of refuse daily, keeps back in his settling tanks some 12 tons of sludge per month. In the case of a dyer in Leeds, with a daily discharge of 40,000 to 50,000 gallons, the wet sludge removed by his settling tanks amounts to some 20 tons a week, and in another case in Pudsey, where the refuse is 60,000 gallons daily, the wet sludge removed from the tanks was formerly 1 ton per day, but this has been greatly reduced, the manufacturer finding it to his advantage to use dyes which produce less sludge. In these cases the preliminary treatment of the refuse is chiefly useful in removing suspended matter, although the mixing of the refuse in the settling tanks tends to precipitate some of the matters in solution. The preliminary treatment of wool-washing, piece-scouring, and silk-boiling suds has a still more important effect. Where the suds are properly treated, the effluent discharged to the sewer, though usually acid from the vitriol used as a precipitant, is freed from grease and suspended solids, and creates little if any difficulty in the treatment of sewage with which it is mixed. Fortunately the preliminary treatment of these liquids is remunerative from the amount of grease recoverable in most cases.

TABLE LXXV.

AVERAGE CRUDE SEWAGES.

(Samples taken every half-hour for twenty-four hours and mixed in proportion to the flow.)

(Results expressed in parts per 100,000.)

No.	1.	2.	3.	4.	5.	6.	7.
Total solids	33·4	83·0	162·3	238·2	116·9	285·9	88·0
Solids in suspension (dried at 100° C.):							
Total	6·8	32·0	70·6	84·6	35·2	91·4	32·3
Ash	2 5	6·9	17·9	28·4	10·9	15·7	6·1
Solids in solution (dried at 100° C.):							
Total	26·6	51·0	91·7	153·6	81·6	194·5	55·7
Ash	22·6	41·7	61·5	122·0	65·7	163·8	44·4
Chlorides (as NaCl)	5·50	14·23	19·00	18 46	23·40	28·10	13·38
Nitrogen:							
Nitric	0·02	nil	3·01	nil	0·04	nil	0·04
Ammoniacal	1·23	4 89	6·70	2·91	1·54	4·94	4·57
Albuminoid (Wanklyn)	0·21	1·15	1·30	1·82	0·71	1·78	1·40
Organic (Kjeldahl)	.	2·34	3·39	3·17	1·66	...	...
Oxygen absorbed from $\frac{N}{80}$ permanganate at 26·7° C.:							
In fifteen minutes	0·46	2·70	5·24	9·40	4·49	15·34	2·73
In four hours	1·02	5·67	11·40	16·30	7·80	24·36	5·45
Total fatty matter	1·09	13·13	39·60	45·30	15·20	46·80	9·77
In solution only:							
Nitrogen:							
Albuminoid (Wanklyn)	0·05	0·34	0·45	0·73	0·22	0·62	0·43
Organic (Kjeldahl)	...	0·53	0·90	...	4·30	...	...
Oxygen absorbed from $\frac{N}{80}$ permanganate at 26·7° C.:							
In fifteen minutes	0·19	1 32	2·10	4·66	2·48	7·25	1·28
In four hours	0·35	2·84	4·62	8·02	3·78	10·15	2·35
Hardness (in terms of $CaCO_3$):							
Total	12 8	18·6	32·6	34·1	15·3	51·1	...
Permanent	10·97	11·4	11·3	22 4	12·1	39·0	...
Temporary	1·83	7·2	21·3	11·7	3·2	12·1	...
Flow in gallons per head in twenty-four hours	125	46	15	45	96	19	99

Preliminary treatment of the trade refuse may not always be necessary or even to the advantage of the Sanitary Authority. For example, new developments in the treatment of sewage sludge may entirely change present views with regard to the reception of greasy liquids into the sewers. At Bradford, Oldham, and Huddersfield Sewage Works, new processes of sludge treatment are being adopted by which the Corporations expect to recover the grease from the sludge and to sell it at a price which will make the process profitable. Again, if such a liquid as waste pickle from wiredrawing is let off suddenly in large quantities into the sewers it may wholly disorganise for the time the operation of sewage purification, acting as an antiseptic and checking bacterial action because of its strong acid reaction. If, on the contrary, it is gradually mixed with the domestic sewage it may help in the precipitation of solids, and thus materially assist in the work of purification.

With the view of testing the effect of regulations such as the foregoing, a series of average samples of sewages from various towns has been taken, and the analyses are given in Table LXXV. The samples were in each case taken from the main outfall sewer during twenty-four hours, after a period of at least three days on which there had been no rain. Care was taken to avoid any day on which the sewage was likely to be specially strong or specially weak, such, for instance, as a washing day or a Sunday. The average composition of the sewages is calculated from the analyses of the samples taken at the different times of day and from the proportional flow of sewage at these times. The samples were taken a few years ago, so that the figures of population, flow, etc., may not coincide with those of the present day, although the conclusions drawn are not affected.

The sewage works chosen were:—

1. *Ilkley*, where the main sewage farm receives the sewage from 1459 houses. The estimated water supply per head of population is 30 gallons, and the only trade refuse is that of one very small brewery. There are some 1300 water-closets in the area drained and 170 waste water-closets. It is evident from the total flow of sewage, and especially from the flow in the early hours of the morning, that very large quantities of subsoil water obtain admission to the sewers.

2. *Harrogate Northern*.—These sewage works receive the sewage of 3800 houses, with an estimated water supply of 30 gallons per head of population. All the houses are provided with water-closets, and there is practically no trade refuse in the sewage.

3. *Hemsworth*.—The number of houses draining to the sewage works is 810, and there is no trade refuse mixed with the sewage. There are only 32 water-closets connected to the sewers, 5 of these being trough water-closets at schools. The water consumption is estimated at 10 gallons per head per day.

4. *Bradford, Frizinghall*.—The number of houses drained to the Frizinghall Sewage Works is approximately 53,000, with some 18,000 water-closets. The estimated water supply is 20 gallons per head for domestic purposes, and 20 gallons per head for manufacturing use There are 122 mills discharging trade refuse to the sewers, at a large proportion of which wool washing is done, the suds being in most cases partially treated for extraction of the grease before reaching the sewers. There are also large quantities of dyewater discharged into the sewers without treatment.

5. *Huddersfield, Deighton.*—The Deighton Works receive the sewage of some 16,000 houses and the untreated trade refuse from 60 mills, three-quarters of which are woollen mills. The domestic water supply is estimated at 17 gallons per head, and the trade supply at 10 gallons per head, and there are over 4000 water-closets connected to the sewers. Apparently large volumes of subsoil or surface water obtain admission to the sewers.

6. *Pudsey, Hough Side.*—The sewage of Pudsey draining to Houghside Sewage Works includes that from some 2400 houses, and the trade refuse, after preliminary treatment, of ten premises, eight being woollen mills, one a tannery, and one a gasworks from which spent gas liquor is discharged. The daily amount of trade refuse is nearly 100,000 gallons; the domestic sewage is chiefly from houses with privy middens, and amounts to 128,400 gallons.

7. *Keighley.*—In Keighley, 8230 houses are drained to the sewage works, and the domestic water supply is 25 gallons per head, giving about 1,000,000 gallons of domestic sewage per day. There are 1500 water-closets, and the contents of 3600 closet-tubs were, at the time the samples were taken, discharged into the sewers between 8 and 9 A.M. Twenty-three mills are drained into the sewers, one discharging dyewater, four wool-washing suds, three yarn-scouring suds, three both wool-washing and yarn-scouring suds, four tannery refuse, three laundry water, two brewery refuse, one refuse from grease-extracting works, one spent gas liquor after extraction of ammonia, and one waste from oil works. The refuse is in nearly all cases partially purified before being admitted to the sewers. Judging from the flow of sewage, there is probably a large quantity of subsoil or spring water admitted to the sewers.

It is abundantly evident from the various analyses given that trade refuse of many kinds is much more difficult and therefore much more costly to purify than ordinary domestic sewage. If any further evidence of this be required, reference may be made to the experience of Bradford with woolcombers' refuse, of Burton-on-Trent and Shepton Mallett with brewery refuse, of Manchester (see Annual Reports of the Rivers Department, 1901, p. 14; 1911, p. 35) and Oldbury (see *Journ. Soc. Chem. Ind.*, 1907, vol. 26, p. 231) with chemical refuse, of Sevenoaks with tannery refuse (see *Attorney-General and Sevenoaks Rural District Council* v. *Whitmore*, "The Times," 25th July 1900), of Southall Norwood with the refuse from a margarine factory (see *Southall Norwood Urban District Council* v. *Middlesex County Council*, 83 L.T. (N.S.) 742), of Norwich with starch refuse, and of Wolverhampton with waste pickle; and several other instances are given by the Royal Commission on Sewage Disposal, 1898, in their Fifth Report, p. 192, where they say that all the trade effluents of which they have had experience interfere with or retard processes of purification to some extent.

In cases where there is a large proportion of trade refuse mixed with the sewage of a town, there is, moreover, a great increase in the amount of sludge produced at the sewage works, and the disposal of sludge is now perhaps the chief difficulty in the treatment of sewage. For example, in twelve towns where domestic sewage only is treated, and where precipitants are used, the average quantity of sludge produced annually, containing 70 per cent. moisture, is one ton for every twelve persons, whereas in other twelve towns where there is a large admixture of trade refuse in the sewage, and where also precipitants are used, one ton of similar sludge is produced annually for every six persons.

The Sanitary Authorities, therefore, who admit trade refuse to their sewers are quite justified in requiring the manufacturers to purify their refuse partially before discharging it into the sewers, or in calling upon them to pay something towards the increased cost of disposal of the sewage, and the manufacturer who can thus get rid of his trade refuse is in a much better position than one who is obliged to purify it effectively so as to be able to discharge it into a stream.

Even when the trade refuse is only taken into the sewers after preliminary treatment, the Sanitary Authorities must expect some increased difficulty in dealing with the sewage besides that entailed by the greater volume, and should therefore be able to charge to the manufacturers some of the greater cost involved. This, however, is not the view of the Royal Commission (see Third Report, par. 29, p. 20), who have no doubt been guided to the opposite conclusion by the fact that a large proportion of manufacturers are already in possession of the right to discharge their refuse into sewers without payment.

Where preliminary treatment is insisted upon, the Sanitary Authority must be prepared to see that the manufacturer constructs efficient works and manages them with sufficient care. This is found to be far from easy, and it is probably the better course to follow the example of Halifax, Heckmondwike, and Huddersfield, where, as has been stated, the Sanitary Authorities prefer to receive the crude refuse into the sewers and to accept payment from the manufacturers towards the extra cost entailed, rather than to insist upon preliminary treatment. In these cases, owing to the fact that the arrangements arrived at were compromises between the Authorities and the manufacturers, many of whom had for long periods discharged their refuse into the sewers without restriction, the payments made do not nearly cover the total cost of purification of the refuse. In other cases, as in Bradford and Brighouse, charges are made by the Authorities sufficient to cover this whole cost, particularly where a manufacturer seeks to make a new connection to the sewers.

Finally, it must be borne in mind that where a manufacturer discharges his refuse into a sewer, the contents of which are not effectively purified by the Sanitary Authority, he may still be held responsible for any pollution of a stream resulting from the discharge of his refuse into it (see *West Riding of Yorkshire Rivers Board* v. *Butterworth & Roberts*, 1909, A.C. 45).

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CHAPTER XIII.

METHODS OF ANALYSIS AND LIMITS OF IMPURITY.

Methods of analysis—Ordinary tests—Special tests—Limits of impurity or standards—Recommendations of Royal Commissions—Growths in streams as signs of pollution—Bibliography.

In the foregoing pages reference has frequently been made to the results of analysis, and in the present chapter it is proposed to indicate briefly how these are obtained, inasmuch as they depend to a considerable extent upon the methods employed.

For a long time chemists have advocated the adoption of standard methods of analysis, and it is understood that the Royal Commission on Sewage Disposal is now considering the question with regard to water and sewage effluents. It will be well if some generally acceptable scheme is thus evolved, for in the analysis of such liquids the adoption of standard methods seems specially advisable. Meanwhile the best that can be done is to record results and to state how they were obtained, as they are thus rendered more useful to other chemists.

With regard to the analysis of waste liquids arising from manufacturing processes, the methods are in the main the same as those employed for water and sewage, but it must be borne in mind that special problems are continually presenting themselves, and these must be solved by the adoption of special methods. Still, it is possible to speak of a routine analysis which includes, besides a note of the physical characteristics, some or all of the following determinations:—

Total solids.
Solids in suspension (dried at 100° C.)
,, ,, Ash.
Solids in solution (dried at 100° C.).
,, ,, Ash.
Chlorides (in terms of sodium chloride).
Ammoniacal nitrogen, from free and saline ammonia.
Albuminoid ,, (Wanklyn).
Organic ,, (Kjeldahl).

Nitrous nitrogen, from nitrites.
Nitric „ from nitrates.
Oxygen absorbed in 4 hours at 26·7° C.
Alkalinity in terms of NaHO.
Acidity „ H_2SO_4.
Hardness (in terms of $CaCO_3$)—Total.
„ „ Permanent.
„ „ Temporary.
Oxygen in solution (c.c. per litre at 0° C. and 760 mm.).

The results, following the procedure of the 1868 Rivers Pollution Commission and the recommendation of a Committee of the British Association appointed in 1898, should be expressed in parts per 100,000, and this is found very useful in comparing the analyses with those of Continental and American chemists, who generally express their results in milligrammes per litre or parts per million. The results are not really parts per 100,000 by weight but centigrammes per litre. As there are, however, 100,000 centigrammes of water in a litre, no appreciable error is generally involved. Equivalents of parts per 100,000, grains per gallon, and milligrammes per litre are given in the following table:—

	Parts per 100,000.	Grains per Gallon (Parts per 70,000).	Milligrammes per Litre (Parts per Million).
1 part per 100,000 . . .	1·00	0·70	10·00
1 grain per gallon . . .	1·43	1·00	14·29
1 milligramme per litre . .	0·10	0·07	1·00

The analysis is generally performed on the thoroughly shaken sample and not on the filtered or settled liquid, as it is the liquid with the accompanying suspended matters which is likely to be discharged into the stream. Occasionally it is necessary to know the nature of the liquid apart from the suspended matters, and in such cases an additional analysis is made after the suspended matters have been removed by filtration.

If the sample contains fibres or lumps of solid matter which would prevent an average portion being taken, and which cannot be broken up by a thorough shaking, these are removed and separately weighed. For this purpose a sieve of brass wire gauze (constructed with wire of 0·0076 inch in diameter, No. 36 S.W.G.), in which there are 1600 apertures to the square inch, is used, and a note is made of the amount and nature of the solids thus removed. The analysis is then made on the liquid which has passed through the sieve.

Physical Characteristics.—Under the heading of Physical Characteristics the appearance of the liquid as to colour, turbidity, etc., is described, the apparent amount and character of the sediment, the odour, and the reaction to litmus paper.

The turbidity is sometimes measured according to a method described by Reid (*Proc. Roy. Soc.*, 1907, B, vol. 79, p. 63), in which the depth of liquid is measured which is necessary to obscure black cross lines, engraved on a white porcelain disc, at the bottom of a two-foot glass tube.

Observations made as to the sensitiveness of the litmus test show that the changes in colour depend upon the length of exposure of the papers as well as upon the amount of acidity or alkalinity of the liquid. Papers supplied by different makers also vary in sensitiveness, the bibulous paper supplied in tins by the Helfenberg Chemical Works Co., Ltd., Dresden, Germany, having been found very sensitive.

Solutions of sulphuric acid containing 1, 2, 5, 7, 10, 15, and 20 parts per 100,000 were prepared and tested with blue litmus paper. The first two solutions did not change the colour of the paper for about two minutes and would be considered as only slightly acid, the others reacted almost immediately. Similar solutions of acetic acid were also prepared and tested. The first two only caused a slight reddening of the paper after four minutes, and would be considered very slightly acid; up to 7 parts the acidity was only slightly marked, about equal to 2 parts of sulphuric acid, whilst above this the acidity was decided. Acidity produced by one part of sulphuric acid or 2 parts of acetic acid per 100,000 was readily noticeable by the taste.

Solutions of caustic soda, containing 1, 2, 3, 5, 7, and 10 parts per 100,000, were also prepared and tested with red litmus paper. With less than 2 parts per 100,000 the alkalinity was not shown by litmus paper; with 2 to 5 parts the reaction was slight, and with more than 5 it was distinct. The first three solutions tasted like distilled water, the fourth and fifth were slightly alkaline, and the taste was distinct with the solution containing 10 parts. It will be noticed that the tongue is not so sensitive to alkalinity as litmus paper, although it is more sensitive to acidity, probably because the secretions of the mouth are usually alkaline.

Total Solids.—This figure is the sum of the solids in suspension and the solids in solution. Only rarely is it the result of a direct determination, which is carried out in the same manner as the estimation of solids in solution.

Solids in Suspension.—In determining these the sample is thoroughly shaken and 50 to 1000 c.c. (according to the amount of sediment) are passed through a filter paper, which has been previously dried in a steam oven at 100° C. until its weight remains constant. In filtering the sample the first runnings are generally passed through the filter paper a second time to get rid of any suspended matter which has escaped. The filter paper with the solids is next washed with distilled water and then dried in the steam oven until constant in weight. The increase in weight gives the amount of solids in suspension in the amount of sample taken.

In determining the ash of the suspended solids the filter paper and solids are transferred to a weighed platinum capsule and ignited in a muffle furnace. The addition of a few drops of ammonium nitrate solution considerably helps the ignition of the filter paper, the ash of which must be allowed for.

Sometimes the liquid is so thick and turbid that it takes days to filter a sufficient quantity to permit of the solids in suspension being determined as above. In such cases direct determinations of the total solids and solids in solution are made, the difference between these figures being returned as solids in suspension. This method is also preferable in some cases where the solids in suspension would be washed away by distilled water. In using such a method it sometimes happens that the ash of the solids in solution is larger in amount than the ash of the total solids, especially in cases where there is a large amount of easily combustible matter in the suspended solids, but the use of a muffle furnace for "burning off" to some extent meets this difficulty.

Solids in Solution.—In estimating the solids in solution, or the total solids when these are estimated directly, a suitable volume (generally 100 c.c.) of the filtrate from the foregoing process, or of the well-shaken liquid, is evaporated in a previously weighed platinum dish, first to a small bulk over a Bunsen fitted with a Rose burner, and then to dryness on a water bath. The dish is then dried in the steam oven until its weight ceases to diminish. The method by which the filtrate is obtained influences the result of this determination. The filter papers generally used are Munktell's No. 1 F, but even clearer filtrates are obtainable by the use of a small Berkefeld filter of infusorial earth, aided by a filter pump, which much hastens the process. The ash of the solids in solution is determined by heating the platinum dish and contents to a dull red heat in a muffle furnace and subsequently weighing.

The platinum dishes are alloyed with 10 per cent. of iridium. Their loss in weight, due to the ignition of corrosive liquids and the cleansing by means of finely powdered bath brick (which has been levigated in a stream of water), has been measured from year to year. Fifteen dishes in constant use gave an average loss per annum of 0·1 per cent., the largest individual loss being 0·2 per cent., and the smallest 0·02 per cent.

Chlorides (in terms of Sodium Chloride).—Chlorides are estimated by titration with a solution of silver nitrate, using potassium chromate as indicator. The method is directly applicable to neutral or slightly alkaline liquids, but not to those which are acid or strongly alkaline. A convenient method of neutralising acid liquids is by means of calcium carbonate, as any excess is easily filtered off. Strongly alkaline liquids are neutralised with nitric acid before titration. In the case of liquids having a strong colour, or much turbidity, or containing sulphides, the sample is evaporated to dryness with the addition of a little lime or sodium carbonate, and ignited gently (a strong ignition volatilises a portion of the chlorides). The residue is then taken up with water, filtered, and the chlorides titrated with silver nitrate. The strength of the silver nitrate solution (14·825 grammes per litre) is such that if 50 c.c. of the effluent are titrated the number of c.c. required multiplied by 10 gives the amount of sodium chloride in parts per 100,000.

Ammoniacal Nitrogen (from free and saline Ammonia).—A suitable quantity of the sample is distilled from a retort or distilling flask containing about 400 c.c. of distilled water, which has previously been made slightly alkaline and boiled free from ammonia, and the distillate is Nesslerised. The volume of liquid taken varies very considerably according to its nature—50 c.c. being generally a suitable quantity—and the quantity taken influences the amount of distilled water used, as sufficient must be used to allow of a large volume of distillate being collected at this stage, and also in the subsequent process for the determination of albuminoid nitrogen.

The distillate is collected in Nessler tubes in portions of 100 or 50 c.c., and the distillation is continued until the final portion gives no coloration on addition of Nessler's reagent (about 2 c.c. to every 100 c.c. of liquid). The amount of ammonia is then estimated by matching the colour produced in the separate portions with that produced by adding Nessler's reagent to a solution containing a known amount of ammonium chloride. This solution contains 0·00001 gramme of nitrogen per c.c. This method of estimating ammonia is so delicate that by its aid, using 1000 c.c. of a water, one part can be detected and estimated in a hundred million parts of the water.

In very clear water the estimation may be made by the direct addition of the Nessler reagent, but even then there is risk of interference by the salts present in solution. Sometimes the distillate is not clear because of substances which have been carried over with the steam, and in such cases the liquid must be filtered through a filter paper which has previously been washed with ammonia-free water, before the addition of the Nessler reagent. These particulate substances, especially fatty matters, distilled over with the steam contain nitrogen in the albuminoid form, but not as free and saline ammonia.

The colour produced by ammonia or salts of ammonia with Nessler's reagent is not produced by ethylamine, aniline, or napthylamine, as might be expected from the similarity in constitution between these bodies and ammonia.

The choice between retorts and distilling flasks is largely a personal matter, the same results being obtainable with both, and neither is more economical in point of time or of breakages. A distilling flask does possess an advantage in the case of liquids which froth considerably or bump violently, but bumping may be effectually prevented by placing two or three small pieces of crumpled platinum foil at the bottom of the retort.

Preparation of Nessler's Reagent.—Dissolve 70 grammes potassium iodide in 200 c.c. of distilled water and 32 grammes mercuric chloride in 600 c.c. of distilled water. Add the second solution gradually to the first until a slight permanent red precipitate is formed and then dilute to 2 litres with a 20 per cent. solution of stick caustic soda which has been boiled to free it from ammonia. Now add more of the mercuric chloride solution in small quantities at a time until a permanent yellow precipitate is just formed. Allow this precipitate to settle and decant the clear supernatant liquid, which is then ready for use.

Albuminoid Nitrogen.—The process used in this determination was devised by Wanklyn in 1867 (*Journal of the Chemical Society*, 1867, vol. 20, p. 445). It aims at estimating the organic matter in a liquid such as a sewage effluent, and depends upon the fact that complex nitrogenous organic bodies in such liquids are partially decomposed, with liberation of ammonia, by boiling them in an alkaline solution of permanganate of potash. This test is not an exact measure of the amount of organic matter present, but rather an estimation of that part of it which is liable to undergo putrefactive decomposition.

To the liquid remaining in the retort after the free and saline ammonia has been distilled off, or to the liquid diluted with ammonia-free water, if only a small volume remains, 25 c.c. (or more in the case of very bad liquids) of an alkaline solution of permanganate of potash (containing 8 grammes $KMnO_4$, and 150 grammes NaOH per litre) are added and the distillation continued as in the previous estimation until no ammonia is present in the last portion of distillate. The ammonia in the distillate is estimated with Nessler's reagent. As in the distillation of free and saline ammonia, substances are sometimes carried over in the steam and must be filtered off before Nesslerising the distillate. These substances contain nitrogen which can be converted into ammonia by prolonged boiling with alkaline permanganate of potash, but this is not included in the results.

In dealing with some polluted liquids containing much organic matter, ammonia continues to come off as long as boiling is continued, and this is another reason for regarding the test as a comparative one rather than an accurate determination.

Organic Nitrogen.—Kjeldahl discovered that boiling concentrated sulphuric acid converts the nitrogen of nitrogenous organic bodies, with very few exceptions, into sulphate of ammonia. By rendering the solution thus obtained alkaline with a solution of caustic soda, and distilling off and estimating the ammonia either with Nessler's reagent or by means of acid of standard strength, we have a method of determining the nitrogen in sewages and trade refuse.

A suitable quantity (about 50 c.c. of an ordinary effluent) of the liquid is heated with 10 c.c. of concentrated sulphuric acid (yielding not more than about 0·00001 gramme nitrogen per c.c. when distilled with caustic soda). In the case of very bad effluents, frothing first takes place, and then about 0·5 gramme anhydrous copper sulphate may be added. The complete destruction of the organic matter is indicated by the liquid becoming clear, a condition which may sometimes be hastened by the addition of a few grammes of potassium sulphate to enable a higher temperature to be obtained. In most cases, however, neither the copper sulphate nor the potassium sulphate are necessary, and the liquid becomes clear in about an hour after boiling has commenced. Very good waters do not blacken during this process, and it is then advisable to add a small quantity of pure cane sugar as an indicator to ensure blackening and subsequent clarification. When this part of the process is complete the remaining liquid is allowed to cool and is diluted with ammonia-free water. A sufficient amount of ammonia-free solution of caustic soda to render the liquid alkaline is added, and the mixture distilled. The ammonia in the distillate is estimated either by Nesslerising or by catching the distillate in acid of standard strength, and from this estimation the amount of nitrogen is calculated. The amount of nitrogen estimated by Kjeldahl's process, less that from free and saline ammonia, is termed organic nitrogen.

In the above distillation, especially if the ammonia is caught in acid, it is necessary to use a flask fitted with a trapped bulb, in order to prevent caustic liquid being carried over with the distillate.

When nitrites or nitrates are present they are partly converted to sulphate of ammonia, thus interfering with the result, but if an attempt is made to correct this error, by first reducing these bodies and estimating their nitrogen along with the nitrogen from free and saline ammonia, it is found that some of the nitrogenous organic bodies are simultaneously decomposed with formation of ammonia.

The ratio of the organic nitrogen to the albuminoid nitrogen affords a rough guide to the quality of a liquid. The former is invariably higher than the latter, and Dr McGowan (Royal Commission on Sewage Disposal, 1898, Fourth Report, supplementary vol. 4, part 5, p. 24) proposes to call the difference between the Kjeldahl nitrogen and the sum of the ammoniacal, albuminoid, nitrous and nitric nitrogens, the "X" nitrogen. This "X" nitrogen is more stable than the albuminoid nitrogen, and as purification proceeds the albuminoid nitrogen is more rapidly attacked than the "X" nitrogen, the proportion of which consequently becomes larger. As to the actual amount of "X" nitrogen occurring in liquids no general statement can be made, but it has been observed that the ratio of the organic nitrogen to the albuminoid nitrogen is fairly constant for liquids of the same class. For good river waters, for example, this ratio is about 6·0, sinking to about 3·0 in more polluted waters. In sewage effluents the ratio is about 4·0 or 3·0, and in crude sewages about 3·0, whilst in grossly polluting trade liquids it sinks as low as 2·0 or even lower.

Nitrous Nitrogen. — The method adopted for this determination depends upon the amount present. The sulphanilic acid method is very delicate and is used to estimate very small quantities. The metaphenylenediamine method is used when the quantity to be estimated exceeds about 0·005 parts nitrogen per 100,000. Both methods are colorimetric.

Sulphanilic Acid Method.—2 c.c. of the reagent known as Griess-Ilosvay solution, prepared by mixing a solution containing 1 gramme sulphanilic acid, 14·7 grammes glacial acetic acid, and 285 c.c. water with an equal volume of a solution containing 0·2 gramme α-naphthylamine, 14·7 grammes glacial acetic acid, and 325 c.c. water (see Fowler, *Sewage Works Analyses*, 1902, p. 64), are added to 10 or 50 c.c. of the effluent in a Nessler glass, when a pink colour is produced if nitrites are present. The pink colour is matched with that produced by known amounts of potassium nitrite present in a standard solution (containing either 0·00001 or 0·000002 grammes nitrogen per c.c. as nitrite) treated in exactly the same manner.

This reaction is so very delicate that effluents containing large amounts of nitrous nitrogen produce such a deep pink tint that it is difficult to match correctly, and in such cases the less delicate metaphenylenediamine method is preferable.

Metaphenylenediamine Method.—A solution containing 8 grammes of the hydrochloride of the diamine in a litre, and another containing 1 part of sulphuric acid to 3 of distilled water are prepared, and 1 c.c. of each of these solutions is added to 10 or 50 c.c. of the sample in a Nessler glass. In the presence of nitrites a yellowish-brown colour (similar to that produced by Nessler's reagent in the presence of ammonia) is produced, and this is matched with that produced by known quantities of the standard potassium nitrite solution as in the previous method.

When nitrites are present in an effluent they absorb oxygen in the potassium permanganate test, with the result that the effluent appears worse than is really the case. In order to measure the extent of the error introduced by neglecting the nitrites, a series of sixty-five sewage effluents was tested, and it was found that the error is so small that it does not cause any alteration in the classification of the effluent as good or bad.

Nitric Nitrogen.—One chief aim in the purification of waste waters is the oxidation of the nitrogen of the organic matter into the form of nitrates. The estimation of these, which are expressed as nitric nitrogen, is therefore of great importance.

The method adopted is the Sprengel or phenolsulphonic acid process (Grandval and Lajoux, *Comptes rendus*, 6th July 1885), misnamed the picric acid process. Of the effluent 25 c.c. are evaporated to dryness in a porcelain basin on the water bath, 2 c.c. of a mixture of equal parts of phenolsulphonic acid and water are added, and the heating on the water bath continued for a few minutes. An excess of ammonia is now added (caustic potash produces the same result and is preferable if the operation is performed in a room where ammonia determinations are being carried out), and in the presence of nitrates a yellow colour is produced. The colour is matched, just as in Nesslerising, with that produced by submitting 10 c.c. of a standard solution of potassium nitrate (1 c.c. containing 0·00001 gramme nitrogen as nitrate) to the same process. The yellow colour obtained in this test varies somewhat, according to the method employed for making the phenolsulphonic acid. It is best prepared by adding gradually a solution of 18 grammes crystallised phenol in 9 c.c. distilled water to 111 c.c. pure sulphuric acid and allowing the mixture to stand in a stoppered bottle for several hours on the water bath.

The method is a very quick one, but yields results lower than the truth in the presence of chlorides (Tatlock and Thomson, *Journal of the Society of Chemical Industry*, 1904, vol. 23, p. 428). Known solutions of sodium chloride and potassium nitrate were submitted to the process, and it was found that the results, in presence of such amounts of chlorides as usually occur in sewage effluents, may be 10 to 20 per cent. below the truth. A simple method of overcoming the difficulty is to remove the chlorides with silver oxide before performing the nitrate test. The addition of strong hydrochloric acid to the phenolsulphonic acid has also been suggested (see Johnson, *Analyst's Laboratory Companion*, p. 81).

The term "picric acid process" originated in a belief that the yellow colour produced is due to the formation of picric acid (trinitrophenol). If this were the case it should be possible to make standard solutions of picric acid (containing known amounts of nitrogen), with which the nitrate solutions after treatment by this process could be matched. This was attempted, but without success (see also *Report of the Massachusetts State Board of Health*, 1890, p. 713).

Attempts were also made to match the colour with mixtures of ortho-, meta-, para-, and tri-nitrophenol, but the tints so produced only served to indicate that the yellow colour is due to a very complicated mixture, probably containing certain proportions of the various dinitrophenols in addition to the above compounds.

Other methods of estimating nitrates have been tested, notably the indigo process, the reduction process with the copper-zinc couple, or with the aluminium-mercury couple, and the pyrogallol process, but none of these possesses the advantages of the phenolsulphonic acid process.

Sewage effluents which contain a fairly large amount of organic matter as well as nitrates undergo changes on standing, the nitrates being partially or wholly used up to oxidise the organic matter, and hence it is necessary to perform the analyses as soon as possible after the samples are taken.

Oxygen Absorbed.—The oxygen-absorbed test, owing to the ease with which it is performed, and the enormous mass of comparable results which has been accumulated, has come to be regarded as one of the most important tests for sewage effluents, and although it does not furnish information as to the nature of the organic matter whose presence it indicates, it is remarkable that the putrescibility of this organic matter may be very well foretold from an analysis which includes the estimation of nitric nitrogen and oxygen absorbed.

The oxygen absorbed is determined by measuring the amount of potassium permanganate decolorised by a known volume of the effluent. The estimation is performed as follows:—Into a 12 oz. well-stoppered bottle are placed 150 c.c. of distilled water and 10 c.c. of dilute sulphuric acid (prepared by mixing one volume of concentrated sulphuric acid with three volumes of distilled water and tingeing the mixture with potassium permanganate in order to destroy organic matter). The bottle is then placed in a vessel of water which is kept at a temperature of 26·7° C.

A suitable quantity of the liquid under examination (50 c.c. are usually taken) is placed in the bottle and successive quantities of 10 c.c. of $\frac{N}{80}$ potassium permanganate solution are added, so that the excess of permanganate, judging from the colour, is never less than about 5 c.c. The bottle is kept in the vessel of water for four hours, being occasionally gently shaken, and more permanganate solution is added as required.

At the end of the four hours 1 c.c. of a 10 per cent. solution of potassium iodide is added and the liberated iodine is titrated with a solution of sodium hyposulphite of strength approximately $\frac{N}{80}$, starch solution being used as indicator. This gives the amount of the hyposulphite solution which corresponds to the unexhausted permanganate. Blank tests are performed in the same manner and at the same time as the former with 10 and with 20 c.c. of the permanganate solution, in order to determine the strength of the hyposulphite solution and the amount of permanganate decolorised by the 150 c.c. water and 10 c.c. acid. The difference between the two titrations of the blank tests gives the amount of hyposulphite which is equivalent to 10 c.c. of the permanganate solution, and the difference between this figure and the amount of hyposulphite required in the blank test with 10 c.c. permanganate gives the amount of permanganate which has been absorbed by the water and acid. By making due allowance for the permanganate decolorised by the water and acid and correcting for the ascertained strength of the hyposulphite solution, the exact amount of permanganate decolorised by the effluent is easily estimated.

The strengths of the above solutions are so arranged that the number of c.c. of permanganate decolorised by 10 c.c. of the liquid gives the oxygen absorbed in parts per 100,000.

Variations in the time during which the action of the permanganate is allowed to proceed have been recommended (*Analyst*, 1881, vol. 6, p. 127), but yield little additional information, except in a few cases where substances are present which have an instantaneous reducing action upon permanganate, and in such cases the three minutes' test may be valuable. It was thought that the result of the four hours' test might be calculated from those of the three minutes' and two hours' tests, and within certain limits this was found to be possible. In order to try this, analyses of a hundred and fifty sewage effluents were made, in which the three minutes', two hours', and four hours' tests were included, and if A, B, and C represent the results of these tests respectively, it was found that $C = B + \frac{1}{3}(B - A)$. This means that the organic matter in the liquid absorbs oxygen rapidly during the first three minutes, more slowly up to the end of two hours, and still more slowly in a further period of two hours, the total amount absorbed during the last period amounting very approximately to a third of that absorbed during the second period.

Some authorities do not add the 150 c.c. of water as in the above method of estimation. One hundred and sixty sewage effluents were examined by both methods, and it was found that higher results were invariably obtained when the sample was not diluted, but that there was no regular relation between the two. It was evident, therefore, that if the results of this test are to be strictly comparable the analysis must always be carried out in the same way (for a discussion on this subject see *Journ. Soc. Chem. Ind.*, 1898, vol. 17, pp. 11, 425). In the tests carried out by the Royal Commission (see Fourth Report, supplementary vol 4, part 5, p. 37) 10 per cent. sulphuric acid and $\frac{N}{8}$ permanganate were used, but this variation from ordinary custom has not met with general approval and scarcely seems warranted. Some two hundred sewage effluents have been tested by the Royal Commission method and by the ordinary method, and it has been found, as was to be expected, that the former invariably gives higher results. The average ratio between the two results was 2·09, but this was by no means constant, varying from 1·00 to 3·39.

In many kinds of trade refuse substances are present which are only partially removed by a purification process, and which have the power of rapidly absorbing large quantities of oxygen, such, for instance, as the sulphur compounds and phenolic bodies in spent gas liquor. In these cases the test by itself is of very little value in determining the putrescibility of the effluents.

Alkalinity or Acidity.—Little need be said about these determinations except as regards the use of indicators. The solutions of acid and alkali used for the titration are $\frac{N}{10}$ hydrochloric acid and $\frac{N}{10}$ caustic soda. In estimating alkalinity phenolphthalein and methyl orange are both used as indicators. In adding acid to an alkaline liquid in the presence of methyl orange the yellow colour only turns to red when sufficient acid has been added to neutralise all the alkali which is present, whether in the free state or combined with carbonic acid. The distinctive pink colour of the phenolphthalein disappears before this point has been reached, namely, when all the free alkali has been neutralised and that present as carbonate half converted to chloride and half to bicarbonate. When it is evident that the alkali is chiefly present as carbonate the result as given by the methyl orange test is set down in terms of Na_2CO_3, $CaCO_3$, or $(NH_4)_2CO_3$, whichever is likely to be present. When, on the other hand, the alkali is chiefly present in the caustic state, the result as given by the phenolphthalein test is set down in terms of NaOH, CaO, or NH_3.

In estimating acidity methyl orange is the indicator generally used, but where the acidity is due to weak acids such as acetic or lactic, phenolphthalein is more reliable, but it must be borne in mind that the latter is affected by carbon dioxide.

Some liquids are so deeply coloured as to hide the changes in the indicators during titration. In such cases the dye present in the liquid may itself act as an indicator, or it may be necessary to use litmus paper, or to note the change which occurs when a drop of the indicator is placed on a white tile and a drop of the titrated liquid added to it.

Hardness.—The hardness of a water or trade effluent is generally due to the presence of calcium or magnesium salts. These produce a precipitate from a soap solution and hinder the formation of a lather, and upon this fact is founded the method of estimating the hardness of a liquid. About 6 grammes oleic acid and 1·5 grammes of potassium carbonate are ground together in a mortar with a little warm water, the mixture dissolved in about 500 c.c. methylated spirits, and the solution diluted with an equal volume of water. A standard hard water is made by dissolving 0·2286 grammes of pure calcite or calcium carbonate in hydrochloric acid, evaporating to expel the excess of acid, and dissolving the residue in one litre of water, making a solution of hardness equivalent to 22·86 parts $CaCO_3$ per 100,000 (or 16·00 grains per gallon). To 50 c.c. of this standard hard water in a well-stoppered 10-oz. bottle the above soap solution is added gradually, 1 c.c. or less at a time; the mixture after each addition is shaken, and the process continued until the lather which forms lasts and covers the whole surface for at least five minutes. The strength of the soap solution must be so adjusted that 16 c.c. are required to produce this result.

50 c.c. of the water to be tested are taken and the soap solution added gradually as above until a lasting lather is formed. From the amount of soap solution required the hardness can then be estimated by comparison with the standard hard water, and it is convenient to use tables which show corresponding amounts of soap solution and hardness expressed in terms of calcium carbonate (see Johnson's *Analyst's Laboratory Companion*). If 50 c.c. of the sample being tested require more than 16 c.c. of the soap solution, the sample is diluted before the test is made.

The hardness as determined in this way is called the "total hardness." Part of this hardness may be due to the presence of bicarbonates of calcium or magnesium, and in order to estimate this a quantity of the liquid is boiled, when, by the escape of carbonic acid, the bicarbonates are converted into carbonates, which are precipitated and can be filtered off. The filtrate is made up to the original volume by the addition of distilled water and its hardness tested as before. This gives the "permanent hardness" of the liquid. The difference between the "permanent hardness" and the "total hardness" is called the "temporary hardness."

Besides the permanence of the lather formed in this test, the alteration in the sound emitted when the liquid is shaken and the feel of the bottle when it is shaken indicate the point when sufficient soap solution has been added.

The results given by the above test might properly be called the "soap-destroying power" of the liquid, and many chemists advocate the employment of Hehner's method of estimating hardness from the alkalinity, but since the objection to calcium and magnesium salts is due largely to their soap-destroying power, the above method has been selected.

Oxygen in Solution.—The oxygen in solution is measured by the process devised by Winkler (*Ber. der deutschen Chem. Ges.*, vol. 21, p. 2843; vol. 22, p. 1764; *Journ. Soc. Chem. Ind.*, 1889, vol. 8, p. 727), and modified by Rideal (*Analyst*, 1901, vol. 26, p. 141). A stoppered bottle containing about 250 c.c. is completely filled with the liquid under examination; to this is added 1 c.c. of a solution formed by mixing equal volumes of concentrated sulphuric acid and water. A standard solution of permanganate of potash is then added drop by drop until a permanent pinkish tint is obtained. The permanganate ensures the oxidation of nitrites, which would otherwise have a disturbing influence.

The liquid is now decolorised by the addition of a few drops of a saturated solution of potassium oxalate, and 1 c.c. of a 33 per cent. solution of manganous chloride and 1 c.c. of a solution containing 33 per cent. of caustic soda and 10 per cent. of potassium iodide are added. This causes the precipitation of white manganous hydrate, which absorbs any dissolved oxygen, turning brown from the formation of manganic hydrate. The bottle is stoppered, taking care to exclude all bubbles of air, and well shaken, and the precipitate allowed to settle, after which 2 c.c. of concentrated hydrochloric acid are added to dissolve the precipitate and liberate the iodine from the potassium iodide. The iodine is then titrated with $\frac{N}{80}$ sodium hyposulphite as in the oxygen-absorbed test, using starch solution as indicator. Each c.c. of the hyposulphite solution corresponds to 0·07 c.c. of dissolved oxygen measured at 0° C. and 760 mm. pressure.

In this test great care is necessary in taking the sample to exclude all bubbles of air and to avoid shaking the liquid. It is best to take the sample in a bucket and then to transfer it to aspirator bottles. These are immersed in the liquid with the top stopper removed, allowed to fill gradually by removing the bottom stopper underneath the surface of the liquid, and then stoppered before they are lifted out of the bucket. Samples of river water may be taken directly in this way.

If the sample is strongly coloured or contains matter in suspension which interferes with the above determination, an aspirator bottle of some 800 c.c. capacity is first filled as above, and into this are introduced (*a*) 3 c.c. of a saturated solution of aluminium chloride to which sodium carbonate has been added until a precipitate is just beginning to form, and (*b*) 3 c.c. of a saturated solution of sodium carbonate. The bottle is corked without allowing any air to enter, well shaken up and allowed to stand, when the precipitated hydrate of aluminium brings down the suspended matter very quickly and leaves a clear and colourless liquid. This supernatant liquid is syphoned into a 250 c.c. bottle and the dissolved oxygen determined as above.

If duplicate samples are collected and one examined on the spot and the other analysed in the laboratory, the latter invariably gives a lower result, some or all of the dissolved oxygen being used up by the organic matter. The test is therefore best performed when the sample is taken. It yields, however, the same results in both cases when the process is carried as far as the formation of the manganous hydrate at the time of taking the sample, and the rest of the process is performed in the laboratory.

It is frequently useful to aerate the sample thoroughly by shaking it with air in a stoppered bottle, dividing it into two, and estimating the dissolved oxygen immediately in one half and in the other after keeping it for twenty-four hours. The effluent may be called unsatisfactory if the amount of dissolved oxygen remaining falls below 50 per cent. of that in the first half (Dibdin, *The Purification of Sewage and Water*, 1903, p. 297; Ramsay, *Chem. Zeit.*, 9th May 1906, p. 432).

It is also useful, in order to imitate what takes place when a liquid is discharged into a stream, to mix the liquid with different volumes of fully aerated tap water and to note the rate at which the oxygen is used up, by ascertaining the amount of dissolved oxygen which remains after the mixtures have been kept for different periods. This is the basis of the method recommended by the Royal Commission (Fifth Report, p. 221, and Eighth Report, p. 2) to be adopted in classifying sewage effluents, and in an Appendix to the Eighth Report instructions are given for carrying out this test.

Putrescibility.—The estimation of the putrescibility of an effluent is regarded by many as a very important test, but although it is comparatively easy to carry out, it does not yield quantitative results as valuable as those yielded by the more difficult estimation of the dissolved oxygen in the various ways described. The simplest form of the test is to keep the effluent in a stoppered bottle, from which all air is excluded, at a temperature of about 26·7° C., representing the temperature of a warm summer day, and to observe the lapse of time before signs of putrefaction occur. These signs are a blackening of the effluent, or of any sediment, an odour of sulphuretted hydrogen, or an increase in the oxygen absorbed in three minutes.

Sometimes ten days or more elapse before an effluent shows signs of putrefaction, and a test of putrescibility taking up less time has been recommended by the Prussian Institute for Research in Water Purification and Sewage Disposal (Spitta and Weldert, *Mitt. aus der Königlichen Prüfungsanstalt*, 1906, vol. 6, p. 160). To 150 c.c. of the liquid is added 0·75 c.c. of a 0·05 per cent. solution of methylene blue (B extra, obtainable from J. J. Griffin & Sons, Ltd , London), and the sample is kept under observation for twenty-four hours to see whether the colour is discharged. If the blue tint remains for twenty-four hours the liquid will not putrefy.

Comparing the results of the test of putrescibility with those of the estimation of nitric nitrogen and oxygen absorbed, it may be stated that, generally speaking, an effluent will putrefy if the oxygen-absorbed figure exceeds 1 part per 100,000 and nitric nitrogen is absent, or if the oxygen-absorbed figure exceeds 2 parts per 100,000 even when nitric nitrogen is present.

Usual Determinations.—The methods detailed above are those in general use in the laboratory, but they are seldom all applied in the examination of a single sample. In examining trade effluents the physical characteristics, the solids in suspension and solution, the oxygen absorbed, the acidity or alkalinity, and the hardness are generally taken as a sufficient guide to the character of the liquid.

Special Determinations.—Besides making the ordinary determinations it is often useful to know the amounts of special substances in a liquid, such as the fats in the refuse of wool washing or piece scouring, or sulphur compounds and tar oils in chemical refuse.

Fatty Matter.—50 to 200 c.c. of the liquid are slightly acidified with sulphuric acid, allowed to stand in a warm place for a short time to aid the separation of the fatty matter, cooled, and then filtered through paper. The paper is then dried in the steam oven and extracted with ether in a Soxhlet apparatus, which contains an extraction thimble, and to which is attached a weighed flask. At the end of the extraction, which usually requires two hours, the ether is distilled off, the flask and filter paper are dried separately in the steam oven, cooled and weighed, the loss of weight of the filter paper or the increase in weight of the flask giving the amount of fat present, and the one figure being a check upon the other.

Sulphur Compounds.—Sulphur compounds may be present in effluents from chemical works where ammonia liquor is manipulated, in the form of free sulphur, sulphides, polysulphides, sulphites, thiosulphates, sulphocarbonates, sulphocyanides or sulphates. The determination of the amount of each of these is a very involved process even in a mixture containing only these substances, but becomes more so in the presence of the other compounds occurring in these effluents. The sulphates are on the whole the least objectionable, hence the practice is to estimate the sulphate sulphur in one portion of the effluent, and to determine the total sulphur in another portion. The difference between the total sulphur and the sulphate sulphur gives the amount of "sulphur in other forms."

The sulphur present as sulphates is estimated by adding hydrochloric acid and precipitating with barium chloride, filtering off and weighing the precipitate of barium sulphate, from which the amount of sulphur can be easily calculated.

The total sulphur is estimated by rendering the liquid alkaline and oxidising by boiling with an excess of potassium permanganate, thus converting all the sulphur compounds into sulphates. The liquid is then boiled with concentrated hydrochloric acid until clear, and the sulphates precipitated with barium chloride. The liquid should then stand overnight to ensure complete precipitation of the barium sulphate, from the amount of which the total sulphur is calculated.

This method of estimating total sulphur possesses an advantage over the one recommended for gas liquors in the Alkali Inspector's Annual Report for 1899, p. 50, in being an oxidation process in alkaline solution, thus preventing a possible loss of sulphuretted hydrogen or sulphurous acid which an acid oxidation process involves. It was suggested by a paper by Lunge on "Oxidation of the Sulphur Compounds occurring in the Manufacture of Caustic Soda" (*Journal of the Society of Chemical Industry*, 1883, vol. 2, p. 460).

The sulphur in the form of sulphocyanides can readily be estimated colorimetrically by adding ferric chloride and sulphuric acid. This produces a blood-red tint, which can be matched with that produced in solutions containing known amounts of sulphocyanide. Great care must be taken to work always with the same amounts of the reagents and the same volumes both of the standard solution and of the liquid to be tested, as the tint produced varies very greatly with the proportion of the reagents present.

Tar Oils.—The tarry matter in the effluents from chemical works is principally in the acid form, although basic and neutral tar oils are also present.

The effluent is acidified with sulphuric acid and well shaken with ether in a separating funnel, and the separated ethereal layer is distilled to remove the ether, the last traces of which are evaporated in the steam oven. The weight of the tarry matter thus obtained is that of the acid and neutral tar oils, which are usually given together as "acid tar oils." The liquid from which these have been extracted is then made alkaline and again submitted to the ether extraction process, when the weight of tarry matter obtained is that of the "basic tar oils."

If the operations of ether extraction be performed in the reverse order, that is, first on an alkaline and then on an acid solution, the basic and neutral tar oils are obtained in the first extract, and in the second the acid. This gives a method of estimating the neutral tar oils, and in such operations these have usually been found to be about the same in amount as the basic, and very much less than the acid.

LIMITS OF IMPURITY.

Every authority dealing with the prevention of pollution of streams has repeatedly been asked by manufacturers to state what standards of purity must be reached before an effluent can be considered fit to discharge to a stream, or, in other words, what limits of impurity are allowable in such an effluent. The request is a natural one, but most difficult to satisfy. The Royal Commission of 1868 repeatedly proposed such standards, and finally recommended (Fifth Report, p. 49) that the following liquids be deemed polluting and inadmissible into a stream:—

> "(*a*) Any liquid which has not been subjected to perfect rest in subsidence ponds of sufficient size for a period of at least six hours, *or* which, having been so subjected to subsidence, contains *in suspension* more than one part by weight of dry organic matter in 100,000 parts by weight of the liquid, *or* which, not having been so subjected to subsidence, contains *in suspension* more than 3 parts by weight of dry mineral matter, or 1 part by weight of dry organic matter in 100,000 parts by weight of the liquid.
>
> (*b*) Any liquid containing, *in solution*, more than 2 parts by weight of organic carbon, or 0·3 part by weight of organic nitrogen in 100,000 parts by weight.
>
> (*c*) Any liquid which shall exhibit by daylight a distinct colour when a stratum of it one inch deep is placed in a white porcelain or earthenware vessel.
>
> (*d*) Any liquid which contains, *in solution*, in 100,000 parts by weight, more than 2 parts by weight of any metal except calcium, magnesium, potassium, and sodium.
>
> (*e*) Any liquid which, in 100,000 parts by weight, contains, *whether in solution or suspension*, in chemical combination or otherwise, more than 0·05 part by weight of metallic arsenic.
>
> (*f*) Any liquid which, after acidification with sulphuric acid, contains, in 100,000 parts by weight, more than 1 part by weight of free chlorine.
>
> (*g*) Any liquid which contains, in 100,000 parts by weight, more than one part by weight of sulphur, in the condition either of sulphuretted hydrogen or of a soluble sulphuret.
>
> (*h*) Any liquid possessing an acidity greater than that which is produced by adding 2 parts by weight of real muriatic acid to 1000 parts by weight of distilled water.
>
> (*i*) Any liquid possessing an alkalinity greater than that produced by adding 1 part by weight of dry caustic soda to 1000 parts by weight of distilled water.
>
> (*k*) Any liquid exhibiting a film of petroleum or hydrocarbon oil upon its surface, or containing, in suspension, in 100,000 parts, more than 0·05 part of such oil.
>
> Provided always, that no effluent water shall be deemed polluting if it be not more contaminated with any of the above-named polluting ingredients than the stream or river into which it is discharged."

They recommended that in regard to river pollution arising from mining operations (*d*) and (*e*) should be suspended, although they hoped that practicable methods would be devised for the purification of such liquids, when these standards could be applied to them also.

The matter was fully discussed when the Rivers Pollution Prevention Act, 1876, was passed through Parliament, but it was found impracticable to adopt this recommendation, and instead it was enacted (Section 4) that no offence against the Act is to be deemed to have been committed by a person causing a polluting liquid to be discharged into a stream by a channel then existing, provided he shows to the satisfaction of the Court that he is using "the best practicable and reasonably available means to render harmless" the polluting liquid. The Royal Commission on Sewage Disposal now sitting has for fifteen years been considering the question, but has not yet come to a final decision. They recommend (Fifth Report, p. 220, and Eighth Report, p. 17) that a standard for sewage effluents should be fixed by statute or prescribed by their proposed Central Authority, and that the Rivers Boards or County Councils should have power, subject to appeal to the Central Authority, to ask for this to be varied according to local circumstances. They suggest (Eighth Report, p. 17) that a sewage effluent would generally be satisfactory if it complied with the following conditions:—

(1) That it should not contain more than 3 parts per 100,000 of suspended matter; and
(2) That, with its suspended matters included, it should not absorb at 18·3° C. more than 2·0 parts by weight per 100,000 of dissolved oxygen in five days.

They have not as yet, even provisionally, suggested any standard for trade refuse effluents, except in regard to distillery refuse discharged into small fishing rivers, in regard to which they say (Sixth Report, p. 17) that an effluent would probably prove satisfactory if it complied with the following conditions:—

(1) That it should not contain more than 3 parts per 100,000 of suspended matter;
(2) That it should be non-putrescible on incubation; and
(3) That, after being filtered through filter paper, it should not absorb more than 1·5 parts by weight per 100,000 of dissolved or atmospheric oxygen in five days.

As the matter is still as it were *sub judice*, and as the final recommendations of the Royal Commission on this subject are likely to be issued at an early date, it seems inadvisable to discuss it at any length in these pages. It should be stated, however, that in the opinion of most of those responsible for enforcing the Acts for the prevention of rivers pollution, fixed standards are not to be recommended, and indeed would be impossible to enforce. Such standards must necessarily be fixed as high as is reasonably possible of attainment by a manufacturer whose premises are favourably situated; but what is possible for him may be quite impracticable for another manufacturer in the same trade whose premises may happen to be hemmed in by other buildings. To take another case, standards which could easily be complied with by a dyer would be almost impossible for a tanner or a woolcomber. Again, the high standards necessary for effluents to be discharged to a stream of small size or in a rural district are quite unnecessary for effluents destined for a navigable river or a stream which is not used for water supply either for man or cattle. If standards were fixed they would in fact bear very heavily upon manufacturers, who are at present safeguarded by Section 4 of the Rivers Pollution Prevention Act, 1876, when they are using the best practicable and reasonably available means to render their waste waters harmless.

In the case of sewage effluents the arguments against fixed standards are not quite so strong, inasmuch as they are produced from one class of liquids and a Sanitary Authority is in a better position than a manufacturer to obtain the necessary site for purification works; but in this case also there is always the difference in streams to be taken into consideration.

It will no doubt be urged that fixed standards have been found of use in the Alkali Works Regulation Acts in dealing with gaseous emanations; but these impurities are discharged into the atmosphere, where any polluting matter is rapidly diffused and where the conditions do not vary as they do in the streams. When liquid discharges are dealt with (Section 5 of the Act of 1906), an offender is only called upon to use the best practicable and reasonably available means for the abatement of a nuisance.

Although there are, as has been stated, strong differences of opinion with regard to the advisability of fixing standards at all, if they are to be fixed, probably all will be agreed as to the correctness of the limit of 3 parts of suspended matter per 100,000, as this is comparatively easy of attainment, while, on the other hand, the discharge of much suspended matter into a stream produces an immediate and noticeable pollution. Even from an effluent which contains the above apparently small amount of suspended matter the stream will receive over a ton of wet sludge with every million gallons of effluent. If this sludge is putrescible, there is a danger that when it collects in the pools of a stream it will there decompose with the liberation of offensive gases.

Even with such an apparently simple matter as the fixing of the above limit for suspended matters in an effluent, the difficulty of dealing with the question on hard-and-fast lines can be realised when it is pointed out that it is only necessary for a manufacturer to dilute his waste waters with a sufficient volume of clean water in order to comply with a requirement such as this.

Growths in Streams.—Any standard adopted must, if it is to be of any service, have reference to the effect produced by the discharge of an effluent into a stream, and this effect cannot be measured solely by a chemical analysis. It is often quite as important to observe the living organisms which inhabit the stream and to note any variations which may be produced by an effluent, such as the disappearance of some forms and the abnormal growth of others. For example, in a stream poisoned by ochre water, practically every form of life, with the exception of a few characteristic algæ, disappears, while, on the other hand, the pollution of a stream by various forms of trade refuse may give rise to profuse growths of special organisms. Discharges, for instance, of spent gas liquor have been found to cause such a growth of *Botrytis vulgaris* as to block up the channel of a small stream, and in other cases to cover the bed of a stream with masses of *Sphærotilus natans*, *Beggiatoa alba*, or *Oospora* and *Fusarium solani*. Bleach-croft refuse has caused a large development of *Sphærotilus natans*, while the effluents from a brewery have been found to favour the growth of *Monilia variabilis*. In the case of a colliery discharging saline water such organisms as *Enteromorpha intestinalis* and *Amphiprora paludosa* have been found in the stream below.

Besides these abnormal growths of special organisms there are also invariably less evident changes in the fauna and flora of the stream, such as result from any pollution, whether by trade refuse or domestic sewage.

This aspect of the question has recently received considerable attention, especially by Kolkwitz and Marsson in Germany, who have classified the commoner organisms according to the amount of pollution in the waters they inhabit. The importance of an examination of these changes in the life of a stream can scarcely be overestimated.

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